CALIFORNIA PORTABLE CLASSROOMS STUDY
PHASE II: MAIN STUDY

FINAL REPORT, VOLUME II
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ABSTRACT

The purpose of the California Portable Classrooms study was to assess environmental conditions in California's portable classrooms. This report documents results from Phase II of the study. Phase II was an in-person monitoring study of a probability sample of all public California K-12 schools with at least one portable classroom. The Phase II field study was conducted in the fall and winter of 2001-02. Three classrooms were monitored in each of 67 schools, usually two portable classrooms and one traditional classroom. In addition to direct environmental monitoring, the study used several data collection forms, including a Facilities Questionnaire, a Teacher Questionnaire, and classroom and Heating, Ventilation, and Air Conditioning (HVAC) check lists, to assess environmental conditions in the sample classrooms. This report describes the sample design, the survey instruments, the monitoring methodology, the data collection process, the data analysis procedures, and the results that show and compare the major characteristics of the populations of eligible public schools as well as the population of portable and traditional classrooms in these schools.

The target population for this study is estimated to consist of 6,506 schools containing 69,447 portable classrooms and 126,322 traditional classrooms. Data were successfully collected in 67 of the 81 eligible sample schools, resulting in an overall weighted school-level response rate of 83%. Data for classrooms had overall study response rates of 57% to 82%, depending on the particular type of data.

Key results include:

(a) School characteristics: 75.8% of the schools were suburban, 17.1% urban, and 7.2% rural; 59.2% were elementary schools, 20.7% middle, and 20.1% high school; 40.1% of the schools have 30 or fewer classrooms, but 4.4% are estimated to have over 30 portable classrooms.

(b) Classroom Characteristics: Portable classrooms are newer than traditional classrooms, and they are more likely to have had a major addition or replacement in the past 3 years, to have carpet or rugs on the floor (and more often with water stains), to be constructed of tack board, fiber/particle board, or plywood (in contrast with traditional classrooms with sheetrock, plaster, or other wall material), to have pressed wood bookcases in the room, and to have a metal roof.

(c) Classroom Complaints or Problems: Higher percentages of facility managers reported problems with portable classrooms – such as water leaks, odors, mold, noise, and temperature – than traditional classrooms. Teachers in portable classrooms complained most frequently about noise (68%), followed by musty odors (67%), unacceptable classroom air (47%), insect occurrences (24%), lighting problems (22%), and past leak or flood in room (20%). Other concerns were reported by less than 10% of the teachers. The percentage of teachers in the traditional classrooms reporting on the same classroom problems was not statistically different from the percentage reported by the teachers in portable classrooms (at the 10% level of significance.)

(d) HVAC Characteristics: In addition to structural differences (physical location of unit, type of fuel, type of unit, and accessibility), indicators of potential

environmental quality were different between the two types of classrooms. Portable classrooms had a higher percentage of HVAC filters that showed the presence of mildew or mold, dirtier drain pans, more clogged drains, and more standing water. The air flow measurements were not significantly different between the two types of classrooms at the 0.05 level; however outdoor air flow (cfm/ft^2) was significantly higher for portable classrooms at the 0.10 level. The average ages of HVAC units were about the same. Indoor levels of CO_2 were significantly higher than outdoor levels, as expected; portable and traditional classrooms were about the same; significant predictors included classroom age, school type, and the teacher rating of indoor air quality.

(e) Light and Noise: The mean light intensity measured in the traditional classrooms was significantly higher than that measured in the portable classrooms (65.2 versus 55.7, respectively). Based on IESNA light guidelines of greater than 30 foot-candles needed to view materials of high contrast, 8.8% of the portable classrooms and 4.4% of the traditional classrooms failed to meet this level of lighting. Similarly 38.3% of the portable and 27.2% of the traditional classrooms failed to meet the requirement for more than 50 foot-candles of light to view materials of low contrast, or small print. Measured noise levels were not significantly different, although teachers in portable classrooms were more likely to turn off the HVAC system due to noise. Based on ANSI/ASA and WHO acoustic standards of less than 35 dBA for unoccupied classrooms, all classrooms failed to meet this level. In fact 50% of the measurements in portable and 37.5% of the traditional classrooms failed to meet the outdoor noise level adopted by a number of cities in California, less than 55 dBA.

(f) Comfort Measures: Temperature levels were more frequently cooler in the portable classrooms than in the traditional classrooms. Portable classrooms also had a higher frequency of relative humidity levels above 60%. Portable classrooms had temperatures below 17 ^oC (63 ^oF) significantly more of the time, 6.3% versus 3.2%. Portable classrooms had temperatures below 20 ^oC (68 ^oF) significantly more of the time, 27% versus 17.0%.

(g) Pollutant Levels (measured in occupied classrooms):

- Based on the Quality Control data, most of the environmental measurement and laboratory data quality was satisfactory.
- Particle Counts: Portable and traditional classrooms had about the same levels except for one $PM_{2.5}$ model where traditionals were estimated to have lower levels than portables. Significant predictors included outdoor levels and presence of carpets/rugs (for $PM_{2.5}$).
- Pollens and Spores: Outdoor levels were generally higher; portable and traditional classrooms had about the same levels; and significant predictors included window position (open or closed).
- Aldehydes –

  Formaldehyde: Indoor levels were higher than outdoor; portable classrooms were higher than traditional classrooms; significant predictors included classroom age, school type, general instruction classroom, and other materials in room. Indoor levels were lower than those measured in the mailed survey (Phase I), but there were many differences in methods, averaging time, and season of year.

Others: indoor levels were generally higher than outdoor levels; portable classroom levels were about the same as traditional classroom levels, except for o,p-tolualdehyde (portables higher).

- VOCs: Indoor levels were higher than outdoor levels; traditional classroom levels were about the same as portable classroom levels; significant predictors vary by specific analyte.
- Metals in floor dust: Portable classroom levels were about the same as traditional classroom levels.
- Pesticides: Portable classroom pesticide mean levels were about the same as traditional classroom levels. Six of the 20 pesticides were detected in over 80% of the classrooms – chlorpyrifos, cis- and trans-permethrin, o-phenylphenol, piperonyl butoxide, and esfenvalerate.
- Polynuclear Aromatic Hydrocarbons (PAHs): Six of 16 PAHs had significantly higher mean loadings (but not concentration levels) for the portables than for the traditional classrooms.
- Animal and arthropod allergens in dust: Portable classroom levels were about the same as those measured in traditional classrooms.

(h) Classrooms in specially-selected schools appeared to have indoor air formaldehyde levels comparable to those in the general target population, but moisture-related problems were more frequently reported than in the general population.

(i) The Phase II study was successful in generating a massive amount of information about California schools and classrooms.

Results from this survey suggest that there are important issues associated with environmental conditions in California K-12 schools that deserve appropriate attention. Furthermore, the environmental factors and complaints reported by the teachers and facility managers in the sampled schools are often different between the traditional and portable classrooms. Measured levels of several pollutants – most notably, formaldehyde – are significantly higher in the portable classrooms than in the traditional classrooms. This study resulted in an extensive, robust database that will generate even more findings with more extensive and varied data analyses.

EXECUTIVE SUMMARY

Background

There are many reasons to study the school indoor environment. School buildings are, by design, densely populated, making the task of maintaining an acceptable indoor environmental quality more difficult than in many other types of facilities. While in these buildings, the children and staff may be exposed to a number of chemicals and biological materials. Children are often more susceptible to health effects and, hence, more likely to be affected by indoor pollution.

Concerns over indoor environmental quality in California's schools have risen recently as the demand for classrooms has resulted in increased reliance on portable classrooms. Portable classrooms are usually constructed with materials and heating, ventilation, and air conditioning (HVAC) systems different from those used in traditional classrooms (Bayer et al., 1998). Manufactured buildings may emit hundreds of chemicals from the particleboard, plywood, fiberglass, carpets, glues, and other materials used in their construction. Adding to potential problems and environmental factors influencing the physical classroom are the specific activities which may be ongoing during the day that could add to already significant "background" concentrations. For example, volatile organic compounds (VOC) emissions of arts and crafts can add to levels of 1,1,1-trichloroethylene, toluene, and xylenes.

To address increasing concerns about portable classrooms, the California Air Resources Board (ARB) and Department of Health Services (DHS) requested funding in the 2000-2001 State budget to jointly conduct a comprehensive study of the environmental health conditions in portable classrooms. The Legislature approved the request, with milestones and requirements specified in AB 2872, Shelley, and California Health and Safety Code (HSC) Section 39619.6. The California Portable Classrooms Study (PCS) is being conducted in response to this legislative mandate. The findings from the PCS will form part of the basis for recommendations that ARB and DHS must make to the Legislature regarding ways to "…remedy and prevent unhealthful conditions found in portable classrooms…" (AB 2872).

The California Portable Classrooms Study was requested by Governor Gray Davis, mandated by the State Legislature, and endorsed by the Superintendent of Public Instruction, Ms. Delaine Eastin. Until this study, there has not been a systematic or comprehensive statewide survey or measurement of indoor environmental conditions in California public schools.

This study was conducted in two phases. Phase I was a mailed survey in which questionnaires and passive formaldehyde monitors were sent to a probability sample selected from all public schools with at least one portable classroom in the spring of 2001. Of 952 eligible schools in the Phase I sample, 426 provided some questionnaire data, and of 800 schools sent formaldehyde samplers, 320 completed formaldehyde monitoring for at least one classroom. Phase II was a monitoring study of environmental conditions in a smaller probability sample selected from all schools with at least one portable classroom both in the spring of 2001 and in the 2001-02 school year. Of 81 eligible schools in the Phase II sample, both questionnaire and environmental monitoring data were obtained for 67 schools.

Results from the PCS will be used by ARB, DHS and other stakeholders to assess the potential for adverse health impacts from environmental conditions and toxic pollutants that may be present in portable classrooms and, where necessary, to identify and implement effective actions that can be taken to remedy or prevent any unhealthful conditions.

This report documents Phase II of the study. It describes the sampling design, the survey instruments, the monitoring methods, the data collection process, the data analysis procedures and programs, and the results that show and compare the major characteristics of the populations of eligible schools, as well as portable and traditional classrooms. The specific objectives were:

- To characterize distributions of pollutants and environmental conditions, by type of classroom, for indoor air, chemical concentrations in dust, and other environmental measures, such as light and noise.
- To characterize indoor/outdoor air associations by type of classroom.
- To characterize performance of HVAC systems.
- To test for significant differences between portable and traditional classrooms regarding indoor air concentrations and concentrations of chemicals in dust.
- To assess the effects of HVAC performance and other factors on indoor air concentrations of pollutants for each type of classroom.

Methods

The Phase II study was an in-school monitoring study that was conducted from October 2001 through February 2002. It utilized a probability-based sample of California public schools having one or more portable classrooms. The sample of schools selected for the Phase II survey, which contained 81 eligible schools, is statistically representative of all California public schools that had portable classrooms in both the spring and fall of 2001 because the sample was randomly selected from all schools on the California Public Schools Directory 2000 (see http://www.cde.ca.gov/cdepress/) that had portable classrooms in the spring of 2001 (based on the Phase I preliminary survey).

Both school-level and classroom-level data were acquired during the study. Classroom data were collected for three classrooms, usually two portable classrooms and one traditional classroom per sample school. Sampling in occupied classrooms was conducted during one school day at each school, with samplers set up in the morning prior to arrival of students, and removed at the end of the day. HVAC testing, noise tests, and measurements of culturable airborne organisms were conducted during lunch breaks. Environmental samples were stored on ice and shipped weekly by overnight delivery.

Field QC checks were performed before and after sampling. Field blanks and controls were collected at a 5% rate. Field duplicates were collected for indoor air pollen and spores, aldehydes, and VOCs. Precision (measured as % RSD) averaged 10% or less across sample types.

Various types of data were collected at each participating school:

- School-level questionnaire data:
  - Facilities Questionnaire II
  - Consultation with Facilities and HVAC Managers (Part 2)
- Classroom-level questionnaire data:
  - Teacher Questionnaire II
  - Consultation with Facilities and HVAC Managers (Part 1)
  - HVAC Assessment Checklist and School Characteristics
- Environmental measurements (moisture, light, noise, and ventilation measurements)
- Laboratory data from environmental samples:
  - Pollen and spores in classroom and outdoor air (Allergenco slides)
  - Formaldehyde and other carbonyls in classroom and outdoor air
  - Volatile organic compounds (VOCs) in classroom and outdoor air
  - Culturable airborne microorganisms in classroom and outdoor air (Mattsen-Garvin samples) (only at specially-selected schools)
  - Culturable surface microorganisms on classroom surfaces (only at specially-selected schools)
  - Metals in classroom floor dust
  - Animal and arthropod allergens in classroom floor dust
  - Pesticides and polynuclear aromatic hydrocarbons (PAHs) in floor dust
- Continuous monitoring data regarding environmental conditions:
  - Carbon dioxide (CO_2), temperature, and relative humidity in classroom and outside air (Q-Trak)
  - Particle counts in classroom and outdoor air
  - HVAC operating status data (on or off) (HOBO)

Statistical estimates of population parameters such as means and proportions were computed using weighted data analysis techniques. SUDAAN software (RTI, 2001) was used to generate estimates of means, proportions and regression coefficients; this software properly accounts for features of the sampling design in the estimation of precision of such estimates (e.g., confidence intervals).

Results

The target population for Phase II of the study is estimated to consist of 6,506 schools containing 69,447 portable classrooms and 126,322 traditional classrooms (195,769 total classrooms). These totals are slightly less than the estimated size of the Phase I population because five schools selected for the Phase II sample were found to have no portable classrooms in the 2001-02 school year (thus those schools were ineligible). From Phase I, it was estimated that there were about 230,000 eligible classrooms in California, and that about 37% of these were portable classrooms. Moreover, the DHS preliminary survey estimated the total number of K-12 public classrooms in the 2000-01 school year was 268,000, of which about 80,000 were portable classrooms.

Data Completeness and Response Rates

Data were successfully collected (questionnaire data and environmental monitoring data) in 67 of 81 eligible sample schools, resulting in an overall weighted school-level response rate of 83.0%. Such a response rate for school-level participation in Phase II of this study is quite good and limits the possibility for nonresponse bias to seriously affect the results. This response rate was much better that the response rate obtained in Phase I of this study (44.7%) for several reasons. The most important reasons were that we used telephone recruitment (rather than mail), we began recruitment early in the school year, we obtained permission from superintendents before contacting principals, and we used three experienced staff members for making recruitment calls to superintendents and principals.

Characteristics of the Population of Eligible Schools

Weighted estimates of population proportions (and of means and percentiles, for continuous measurements) were generated for selected items from the data collection forms. Among the many estimates produced, the following *school* characteristics were most notable:

- The schools were about equally split between Northern and Southern California (45.5% in the north and 54.5% in the south).
- The schools were mostly suburban schools (75.8% suburban, 17.1% urban, and 7.2% rural).
- The schools were mostly elementary schools (59.2% elementary, 20.7% middle, and 20.1% high school, based on the highest grade offered).
- Many of the schools (40.1%) had 30 or fewer total classrooms, but 4.4% were estimated to have over 30 portable classrooms.
- Most of the schools (87.9%) performed regular HVAC inspection and maintenance.
- About half of the schools (58.7%) reported having HVAC maintenance logs, which are required by State regulations.
- Many of the schools (41.7%) were aware of EPA's Tools for Schools program, but few (18.7%) reported using this program.

These results are consistent with the Phase I findings, except that the awareness and use of the EPA's Tools for Schools program has increased slightly.

General Characteristics of the Population of Eligible Classrooms

Some general characteristics estimated for the eligible *classroom* population are the following:

- About 63.1% of the classrooms were located in Southern California.
- The classrooms were mostly in suburban schools (75.5% suburban, 17.8% urban, and 6.6% rural).
- The classrooms were mostly in elementary schools (59.0% elementary, 22.9% middle, and 18.1% high school, based on the highest grade offered).

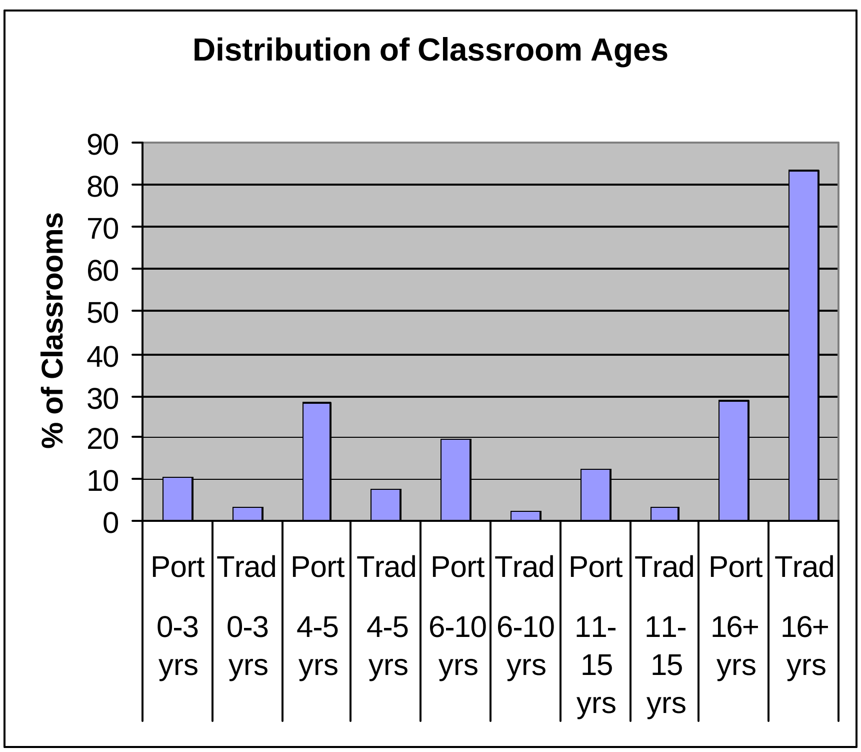
These results are comparable to those observed in Phase I of the study.

General classroom characteristics that were found to be significantly different (at the 5% significance level) between traditional and portable classrooms include the following:

-
- Portable classrooms (PORT) usually were newer than traditional classrooms (29.1% versus 83.4% over 15 years old). (See Figure ES-1.)
- Portable classrooms were much more likely to have had a major addition or replacement in the past 3 years (83.6% portable classrooms versus none observed for traditional classrooms).
- Portable classrooms were more likely to have carpet or rugs on the floor (82.0% versus 62.9%).
- Portable classrooms were more likely to have water stained floors (13.1% versus 2.0%).
- Portable classrooms were more likely to have tack board, fiber/particle board, or plywood walls, whereas traditional classrooms were more likely to have sheetrock, plaster, or other wall material.
- Portable classrooms were less likely to have chalk in the room (21.6% versus 40.8%).
- Portable classrooms were more likely to have pressed wood bookcases in the room (73.1% versus 49.8%).
- Portable classrooms were more likely to have a metal roof (28.5% versus 2.5%).
- Portable classrooms were used somewhat less frequently for general classroom instruction (87.9% versus 96.5%).
-

Moreover, the estimated distribution of the height of the foundation skirt for portable classrooms was as follows: 42.6% are less than 2”, 22.2% are from 2” to 12”, and 35.2% are over 12”.

Figure ES-1. Portable Classrooms Usually were Newer than Traditional Classrooms



Ventilation/HVAC Characteristics

Phase II provided more in-depth information about HVAC characteristics and comfort indicators than did Phase I. Several of the items from the data collection forms pertain to the condition and operation of the HVAC systems serving the classrooms. Several significant differences between portable and traditional classrooms were observed regarding HVAC characteristics:

- Teachers were more likely to turn off the HVAC system due to high noise levels in portable classrooms (68.3% versus 42.2%).
- The HVAC unit was more likely to be wall mounted in portable classrooms (79.8% versus 9.3%).
- The HVAC unit was more likely to be a heat pump in portable classrooms (94.6% versus 76.9%).
- The heating fuel was more likely to be electricity in portable classrooms (98.1% versus 79.3%).
- The air handling unit was more likely to have good access to its interior in portable classrooms (66.1% versus 35.3%).
- The air filter was more likely to have a lighter loading of dirt in portable classrooms (51.6% versus 42.9%).
- The size of the gap around the filter was more likely to be less than 1/2” in portable classrooms (71.6% versus 46.3%).
- The air handling unit was less likely to have clean condensate drain pans and lines in portable classrooms (30.0% versus 56.7%).
- In the drain test, the air handling unit was more likely to have standing water for portable classrooms (55.3% versus 11.1%).
- A blocked drain was more likely to be observed during the drain test in portable classrooms (36.6% versus 6.8%).
- In portable classrooms the air handling unit was more likely to fail the drain test (58.5% versus 12.4%).
- The air intake was blocked on the air handling units more often for portable classrooms than for traditional classrooms (10.8% versus 2.7%).

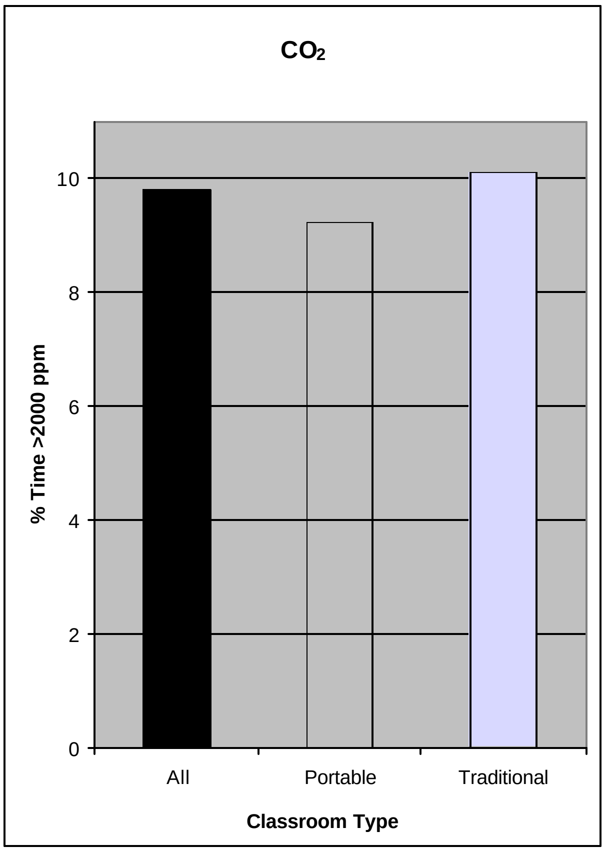
Mean differences in outdoor air flow, total supply air, and HVAC age were not significantly different (at the 5% level of significance) for portable versus traditional classrooms. (See discussion of CO_2 levels below.) However, outdoor airflow (cfm/ft^2) was significantly higher for portable classroom at the 0.10 level.

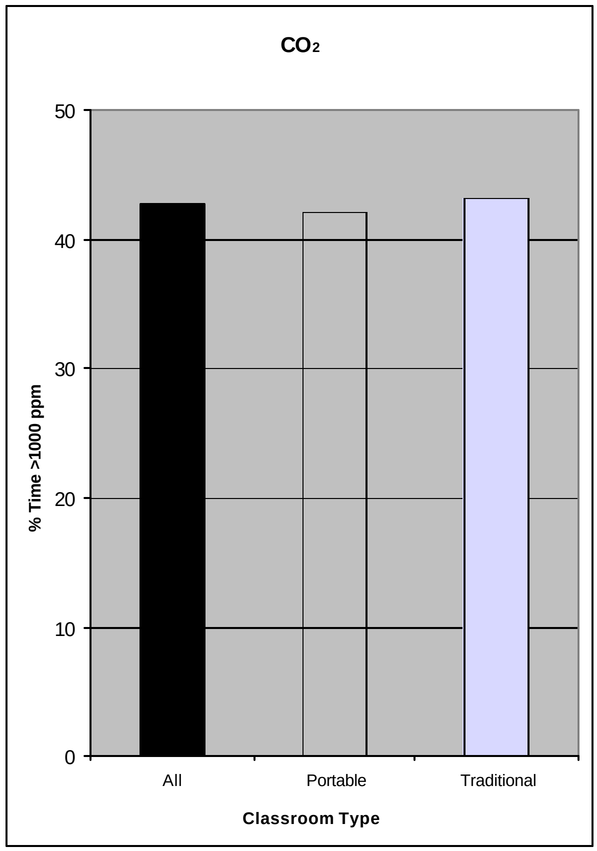
The mean CO_2 concentrations were not statistically different for the portable and traditional classrooms. Average indoor levels (1070 ppm) were more than twice as high as outdoor levels (427 ppm). As can be seen in Table ES-1, both portable and traditional classrooms had school-day average concentrations of carbon dioxide (CO_2) greater than 1000 ppm. This table and Figure ES-2 show that both classroom types had one-hour average CO_2 levels above 1000 ppm for about 40% of the school day. Both classroom types had one-hour average CO_2 levels above 2000 ppm for about 10% of the school day. These results indicate insufficient ventilation in a substantial portion of California classrooms.

Table ES-1. CO_2 Levels as an Indicator of Ventilation Sufficiency

	Portable	Traditional	All
mean ppm across school day	1064	1074	1070
% with one-hour average above 1000 ppm (mean)	42.1	43.2	42.8
% with one-hour average above 2000 ppm (mean)	9.2	10.1	9.8

Figure ES-2. CO_2 Levels in Portable and Traditional Classrooms Were Similar





Lighting and Noise Characteristics

There was no significant difference between portable and traditional classrooms for the teachers' opinions regarding whether or not the classroom lighting was satisfactory. However, the mean light intensity in the center of the classroom was significantly higher for traditional classrooms than for portable classrooms (65.2 versus 56.7 foot-candles). Sampled portable classrooms failed to meet the IESNA light guidelines of 30 f-c for high contrast at double the rate of traditional classrooms, 8.8% versus 4.4%. They also failed to meet the IESNA light guidelines of 50 f-c for low contrast at a higher rate, 38.2% versus 27.2%.

All of the classrooms failed the 35 dBA ANSI acoustic standard for classrooms. In fact, 50% of the noise measurements taken indoors for the portable classrooms failed to meet the outdoor noise nuisance standard (< 55 dBA) adopted by a number of cities in California. (See Figure ES-2). None of the HVAC noise measurements were significantly different (at the 5% significance level) between portable and traditional classrooms. (See Figure ES-3.)

Temperature and Humidity Levels

A relatively large percentage of the classrooms in California do not achieve the ASHRAE standards for acceptable temperature and relative humidity. Portable classrooms had temperatures below 17 EC (63 EF) for more of the time (6.3% versus 3.2%); and they had temperatures below 20 EC (68 EF) for more of the time (27.0 % versus 17.0%). Both portables and traditionals exceeded 23 EC (73EF) about 27% of the time, but traditionals had a higher percent of time at very high temperatures (> 26 EC [79 EF] and > 29 EC [84 EF]) (see Figure ES-4).

None of the relative humidity (RH) summary measures exhibited statistically significant differences between the means of the two types of classrooms that were statistically significant at the 5% level. Average RH measurements were 46.8% and 45.9% for portable and traditional classrooms, respectively, within the acceptable range. However, as can be seen in Figure ES-5, California classrooms do not achieve the ASHRAE standards for acceptable relative humidity a substantial portion of the time.

Pollutant Levels

Particle Counts in Air. Real time counts of particles were measured in each classroom and outdoors. It should be noted that particle counts cannot be directly associated with mass concentration standards; however, the measurements do provide a relative indication of mass for comparison purposes. Mean counts of particles per minute for particles of 2.5 µm or less and for particles of 10 µm or less were not significantly different for portable and traditional classrooms. However, the 95th percentiles for particle counts for these two particle sizes were much higher in the portable classrooms, especially for the small size range. One possible explanation, as mentioned before under the characteristics of the classrooms, is that carpets and rugs were found more often in the portable classrooms, which could be a source of the particles.

Pollens and Spores in Air. In general there were few spore types that were observed frequently in either the outdoor or indoor environments. In the outdoor environment, only six were frequently seen (on 80% or more of the slides)—Amerospores, Ascospores, Cladosporium, Mycelial Fragments, Pollen Count, and Total Fungal Spores. Not too surprisingly, all of these except Ascospores were frequently found (80% or ore of the slides) indoors. No significant differences between portable and traditional classrooms were found for mean Total Pollen Counts or mean Total Fungal Spores.

Figure ES-3. Portable and Traditional Classrooms Mean Noise Levels Were Above the Outdoor Noise Nuisance Standard (< 55 dBA), but Not Significantly Different

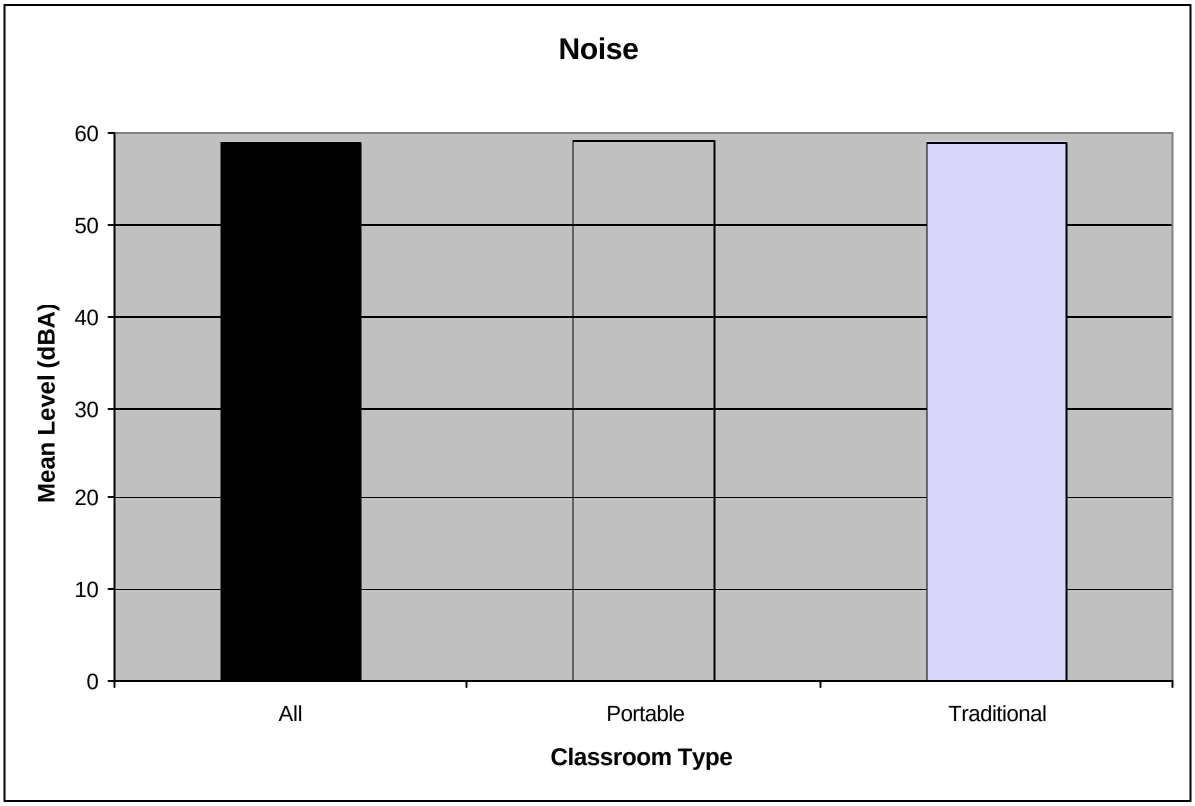


Figure ES-4. Portable Classrooms were More Frequently Cooler (< 20° C [68 EF]) and Less Frequently Warmer (> 26° C [79 EF]) than Traditional Classrooms

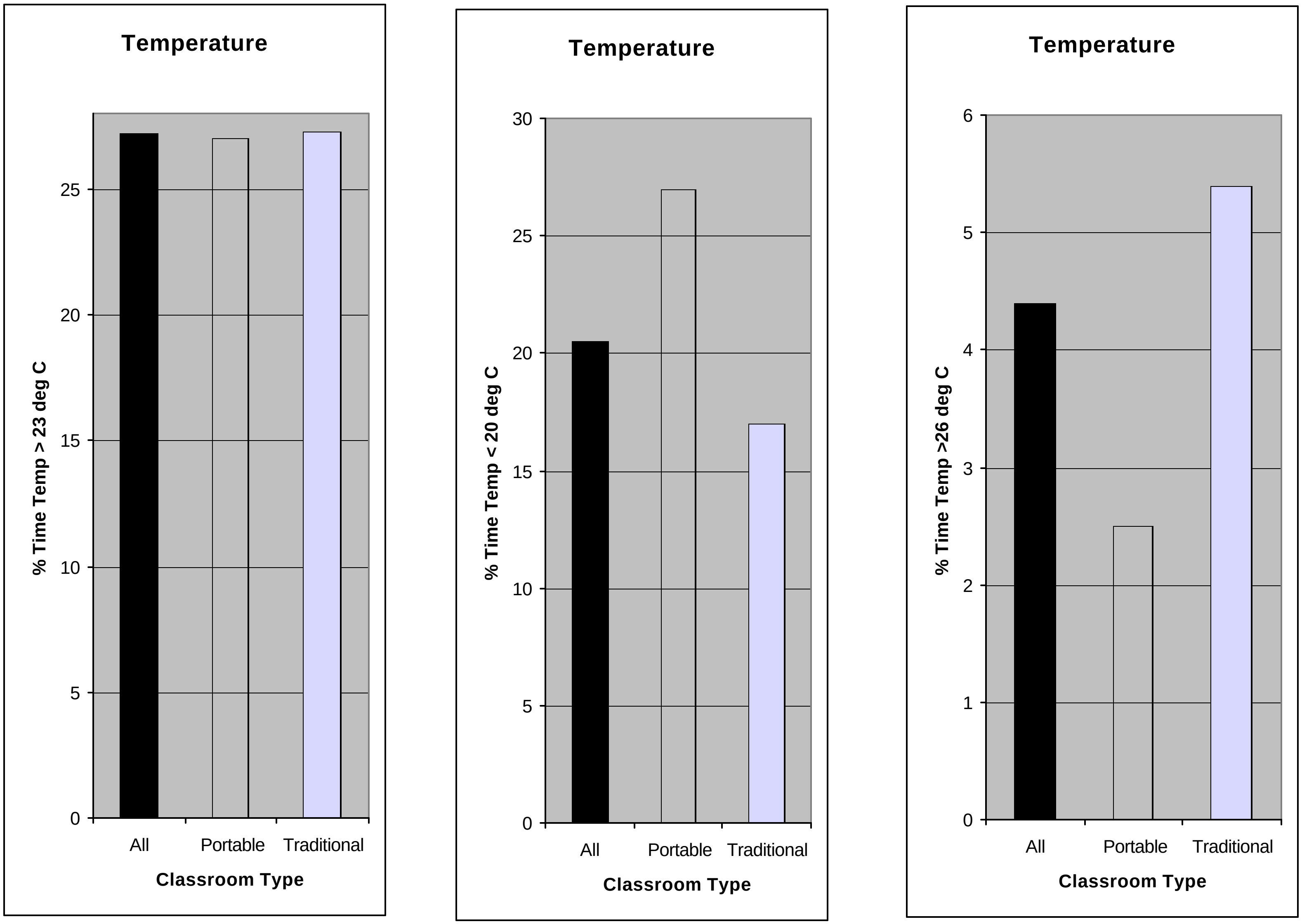
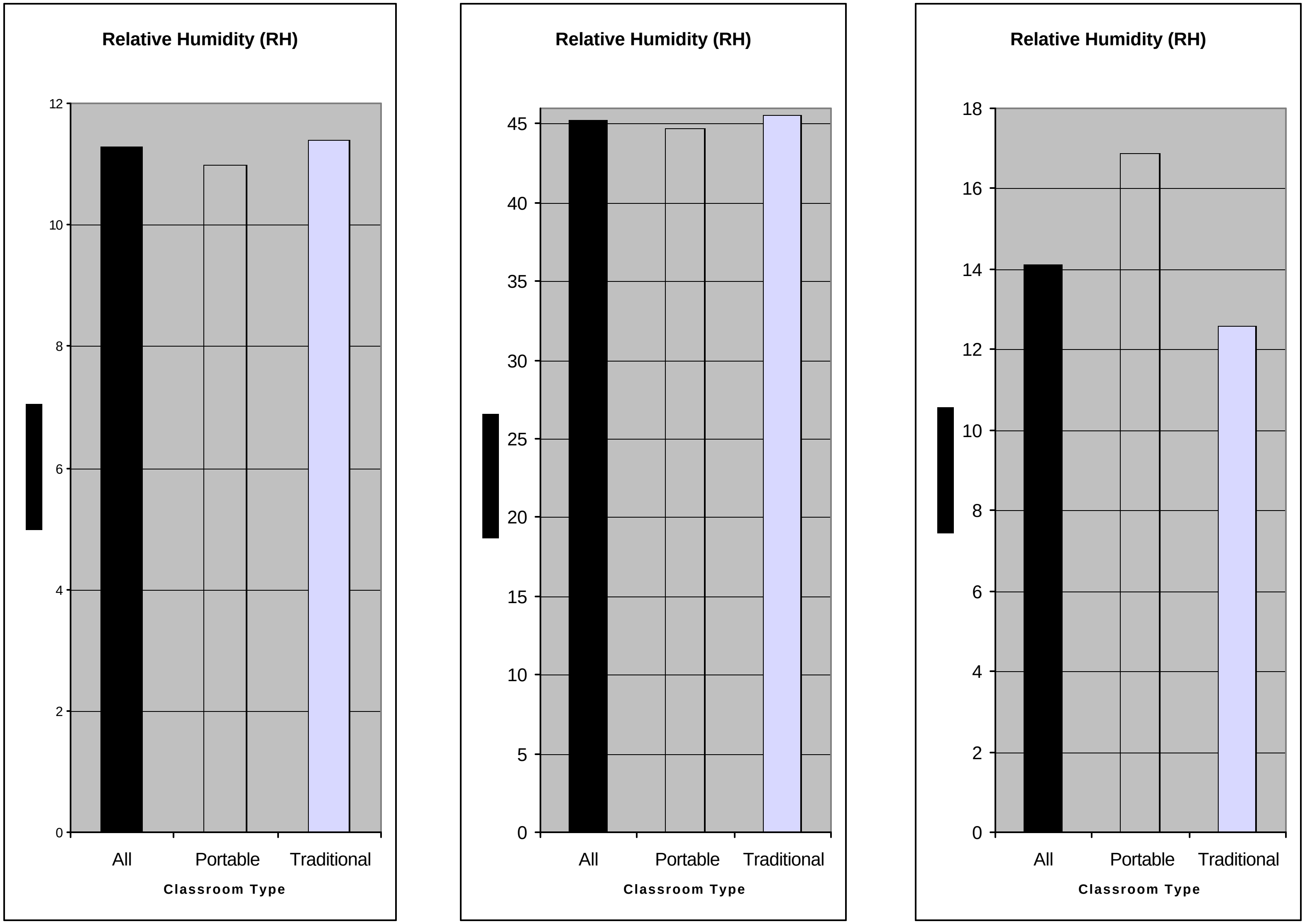
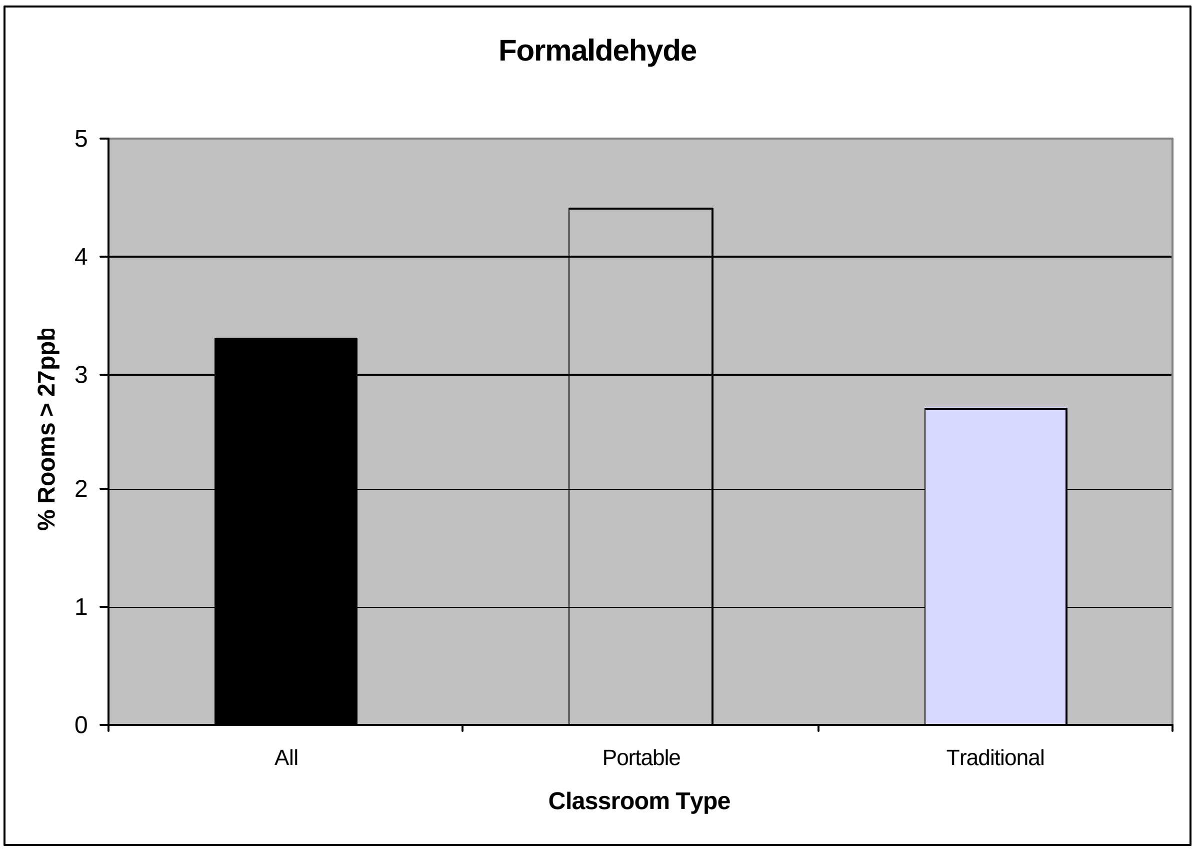


Figure ES-5. Average Percent of Time Classrooms were Outside ASHRAE Standards for Relative Humidity



Aldehydes in Air. Of the 13 specific aldehydes included in the analysis, only two were detected in more than 75% of the samples – formaldehyde and acetaldehyde. For virtually all of the aldehydes, the indoor levels were higher than the outdoor levels, indicating the presence of indoor sources. Formaldehyde, for example, had an overall mean level of 13.3 ppb indoors, but only 3.5 ppb outdoors, while the indoor-air 95^{th} percentile was 3 times higher than outdoors. About 3.3% of the classrooms exceeded 27 ppb, the draft 8-hour Indoor Reference Exposure Level (see Figure ES-6). Statistically significant differences between mean levels in portable and traditional classrooms were found for two analytes at the 5% level of significance:

Figure ES-6. Percentage of Classrooms With Formaldehyde Levels Above the 8-hour Indoor Reference Exposure Level (27 ppb)



- Formaldehyde (mean of 15.1 for portables versus 12.3 ppb for traditionals)
- o,p-Tolualdehyde, although this analyte had a low percent of classrooms with measurable levels (~20%).

The distributions of formaldehyde measurements from Phase I and Phase II of this study were compared, even though there were many differences in the data collection methods and protocols. The Phase I measurements used PF-1 passive monitoring tubes sampling over 7 to 10 days, including nights and weekends when the schools were closed and HVAC systems may have been off, whereas the Phase II measurements used an active monitoring device during the 6 to 8 hours when classes were in session and HVAC systems were operating normally. Moreover, the Phase I measurements were obtained mostly in the spring and early summer, whereas the Phase II measurements were obtained in the fall and winter. Given these differences (colder weather and better air exchange during the monitoring period), it is not surprising that the Phase II formaldehyde concentrations were considerably lower than those observed in Phase I, as noted in Table ES-2.

Table ES-2. Summary of Formaldehyde Concentrations in Air (ppb)

	Sample size (n)		Mean (ppb)		Median (ppb)		95th Percentile (ppb)	
Location	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
Outdoor	NA	62	NA	3.48	NA	2.45	NA	8.05
All classrooms	911	199	27.0	13.29	22.0	12.01	61.7	23.93
Portable	644	135	32.4	15.07	27.1	14.49	71.5	25.78
Traditional	267	64	23.7	12.31	20.0	11.62	55.0	22.35

Volatile Organic Compounds in Air. Seven of the nine measured VOCs had at least 80% of their measured levels above the detection limit. There was a general tendency for the traditional classrooms to exhibit higher VOC concentrations than the portables, but none of the differences in mean concentrations were significant statistically, even at a significance level of 10%. As in most indoor air quality studies, the measured indoor VOC concentrations were higher than those observed outdoors. Average in-room concentrations ranged from a high of 6 $\mu g/m^3$ for toluene (slightly less for m,p-xylene, around 5 $\mu g/m^3$) to less than 0.5 $\mu g/m^3$ for chloroform. For all others, the averages were in the range of 1 to 2 $\mu g/m^3$.

Metals in Floor Dust. Samples of floor dust from the three sampled classrooms were collected using a hand-held vacuum dust collector (Data Vac II) and using a specialized protocol to attain as great a consistency as possible in sample collection. The samples were stored on ice for shipping and frozen until analysis. The samples were sieved at two cut points, less than 500 microns for the portion sent to California DHS for analysis of allergens, and the remainder of the dust was sieved again at less than 150 microns for consistency with reported chemicals in house dust. Equal aliquots of the sample collected from the portable classrooms were combined for further chemical analysis to reduce costs. Accordingly, there was one sample analyzed to represent the portable classrooms, and there was one sample analyzed to represent the traditional classrooms at each school. Results were reported in concentration units ($\mu g/g$) and loading (ng/cm^2).

Fifteen of the 18 elements were above the detection limit for all of the samples analyzed. The only three that were not always above the detection limit were selenium (54%), cobalt (64%), and palladium (34%). Of the 15 elements, the median concentration in composite samples from portable classrooms was greater than the median concentration in samples from traditional classrooms for 8 of the 15 elements (arsenic, chromium, copper, manganese, vanadium, cesium, iron and strontium). Conversely, the traditional median was higher than the portable for the other 7 elements, including lead. When the floor dust metals results are reported in terms of dust loading, all the elements show higher results in the portable classroom samples, except copper. However, none of these differences were statistically significant at the 0.10 level of significance.

Lead, Arsenic and Chromium concentration results ($\mu g/g$) and loading results (ng/cm^2) for the median and 95th percentile are shown below in Table ES-3. It illustrates that there are not clear cut patterns across the elements, and probably reflects the close proximity of sources. For example, since the portable classrooms are generally newer, the lower concentration of lead may reflect the number of years accumulation of the particles in the classroom. Arsenic, on the other hand, might indicate closer proximity to the school grounds where there may be treated wood.

Table ES-3. Concentration and Loading Results for Selected Elements

Element	Room Type	Concentrations (: g/g)		Loadings (ng/cm^2)	
		Median	95th Percentile	Median	95th Percentil
Lead	All	85.4	189.5	6.5	58.4
	Port	67.4	151.6	5.8	57.9
	Trad	95.5	200.6	7.1	57.5
Arsenic	All	11.6	17.3	1.3	5.5
	Port	12.7	18.6	1.6	5.5
	Trad	10.9	15.3	1.1	3.4
Chromium	All	36.6	72.8	3.4	17.8
	Port	35.8	54.1	3.9	23.9
	Trad	37.0	74.0	3.2	12.6

Pesticides in Floor Dust. Portable classroom pesticide mean levels were about the same as traditional classroom levels. Six of the twenty measured pesticides were detected in over 80% of the samples – chlorpyrifos, cis- and trans-permethrin, o-phenylphenol, piperonyl butoxide, and esfenvalerate. Esfenvalerate had the highest median concentration level (3.83 : g/g). It also had the highest median loading level (0.34 ng/cm^2), while many of the pesticides had median loading levels less than 0.01 ng/ cm^2).

PAHs in Floor Dust. Most of the 16 PAHs were detected in over 80% of the samples, but the loadings were generally very low. Only 5 of the PAHs had measured concentrations above 1.0 : g/g; these included chrysene, fluoranthene, pyrene, indo[1,2,3-cd]pyrene, and perylene/benzo[b]fluoranthene.

Comparing the portable classroom concentrations with the traditional classrooms, 9 of the PAHs were measured at higher median levels in the composite portable classroom samples, while two of the PAHs were measured at higher median levels in the traditional classrooms (fluorene and perylene/benzo[b]fluoranthene). Similar results can be seen using the 95th percentile of the distribution as the statistic for comparison: 15 of the 16 PAHs were higher in the portable classroom samples. (Naphthalene was measured at equal levels in both types of classrooms.)

Animal and Arthropod Allergens in Floor Dust. Weighted distributional statistics characterizing the allergen levels from sieved dust samples (dust particles less than 500 Fm) that were collected in the sample classrooms revealed that Canis f1 and felis d1 were detected in 56% and 74% of the samples, respectively, while the other species were detected less than 10% of the time. The traditional classrooms had higher estimated concentrations for each species than the portables, but the differences were not statistically significant. The Canis f1 average concentration was about double the Felis d1 average concentration (0.43 versus 0.26).

School Reports of Environmental Problems or Complaints in the Past Year. Several differences are noted between the proportions of schools that reported environmental problems with, or complaints regarding, environmental conditions in their portable and traditional classrooms in the past year. Table ES-4 shows that higher percentages of schools reported environmental problems and complaints regarding environmental conditions for their portable classrooms. Higher percentages of schools reporting problems or complaints regarding their portable classrooms is consistent with the Phase I findings; however, the percentages of schools reporting problems or complaints is uniformly lower for both portable and traditional classrooms.

Table ES-4. Percentages of Schools Reporting Environmental Problems or Complaints in the Past Year

Problem/Complaint	Portable (%)	Traditional (%)
Roof leak	24.3	12.0
Plumbing leak	4.3	2.6
Air quality/odor complaint	20.2	7.0
Mold complaint	13.4	4.4
Temperature complaint	15.8	17.2
Noise complaint	4.3	0.1
Environmental conditions complaint	32.2	18.9

Factors Affecting Indoor Environmental Quality

Factors Affecting Indoor-Air Pollen/Spores. A number of different models were fit for log (Pollen Count) and log (Total Fungal Spores). Key findings were:

- There was a statistically significant[1] association between indoor and outdoor levels – with higher outdoor levels being associated with higher indoor levels.
- The portable and traditional classrooms were not significantly different when outdoor air levels were controlled in the model.
- The tests for significance for the candidate predictors revealed that only one predictor exhibited statistical significance – namely "windows open," which indicated that classrooms with "windows open today" tended to have lower pollen counts.

Factors Affecting Indoor-Air Aldehyde Concentrations. Various models were fit for log (Formaldehyde Concentration), log (Acetaldehyde Concentration), and log (o,p-tolualdehyde Concentration). The preferred models for the three species were quite different. For formaldehyde, the type of classroom was generally statistically significant, with portables having higher levels. Acetaldehyde showed no significant differences for portable and traditional classrooms while the models for o,p-tolualdehyde included a significant room-type by outdoor-air interaction. They both showed significant associations with their outdoor levels, while the formaldehyde models generally did not show a relationship with the outdoor levels. Two variables showed the strongest positive relationships with indoor formaldehyde levels: indoor CO_2 and indoor relative humidity. These two models, with adjustments for outdoor air formaldehyde levels and/or classroom type, accounted for 22% and 32%, respectively, of the total variation in the indoor levels. The model including "pressed wood bookcases" as a predictor, which also included a significant classroom age variate (positive slope), accounted for

[1] Except where noted, a significance level of 0.05 was used to judge statistical significance of model terms.

only about 14% of the total variation in the indoor formaldehyde levels. However, this model implied about a 30% increase in formaldehyde levels when pressed wood bookcases were present, and about 30% higher concentrations for portable classrooms. The model for acetaldehyde that included "pressed wood bookcases" as a predictor accounted for about 24% of the total variation in the indoor levels of that analyte, and indicated a significant increase in the indoor levels when pressed wood bookcases were present. Unfortunately, the disparate classroom age distributions for portable and traditional classrooms and the small sample sizes for newer traditional classrooms made separation of the classroom type and classroom age effects infeasible.

Factors Affecting Indoor-Air VOC Concentrations. Models were fit for five VOCs (log-scale concentrations) using various candidate predictors. There were significant associations with outdoor levels in virtually all of the VOCs, except for benzene, and these associations appeared somewhat stronger than for the aldehydes. Toluene and m,p-xylene models indicated that the outdoor association varied by classroom type. The toluene and xylene models showed no relation with outdoor levels for portables, and a positive relation for traditional classrooms.

A number of the significant effects for the predictor variables were counter-intuitive. For example, for tetrachloroethylene, a significant negative association with presence of carpet/rugs was detected, perhaps suggesting that carpets/rugs were acting as a sink. For toluene, significantly lower levels were estimated when new construction/repair activities were on-going (which may reflect the fact that doors and windows might be more frequently closed when those activities were outside of the immediate classroom). The variables in this model accounted for 69% of the total variation in indoor toluene levels.

Factors Affecting Indoor-Air CO_2 Concentrations. Two summary CO_2 measures were modeled: log (CO_2 Concentration), and percent of time CO_2 concentrations exceed 1000 ppm. Among the candidate predictors that were considered, classroom age had a significant positive relationship with the log (CO_2) levels. Also, there was a significant positive relationship between indoor and outdoor concentrations. However, the inclusion of the teacher's rating of IAQ in the log (CO_2) model resulted in a significant interaction effect between classroom type and outdoor CO_2 levels. A positive relation with the outdoor levels remained for the portables, but not for the traditionals. Based on this model, the indoor CO_2 levels were estimated to be approximately 30% lower when the teachers reported that the IAQ was acceptable. Models for both CO_2 measures also showed a significant effect of school type, with high schools having the highest indoor CO_2 levels.

Factors Affecting Indoor-Air Particle Counts. Models were fit for log (average number of particles/minute # 2.5 Fm) and log (average number of particles/minute # 10 Fm). Among several potential predictors considered, the only predictor showing significance (other than outdoor particle levels) was the "presence of carpets/rugs" which showed lower $PM_{2.5}$ particle counts for rooms with carpets/rugs. For that model, traditional classrooms showed significantly lower particle counts than the portable classrooms. Both particle measures exhibited significant interactions, at the 0.07 level of significance, between room type and the outdoor particle levels.

Factors Affecting Noise Associated with HVACs. The noise level (dBA) measured near the register when the HVAC unit was on was modeled. Of the candidate predictors, only classroom age was statistically significant. For that model, classroom age had a positive effect (older rooms had higher noise levels) and the portable classrooms had significantly higher noise levels than the traditional classrooms. This model only accounted for only about 11% of the total variation in the noise level, however.

Factors Affecting Indoor Temperatures. Two temperature measures were modeled: percent of time that the room was below 20EC (68EF, too cool) and percent of time that the room was above 23EC (73EF, too warm). For the latter outcome, only two predictors were significant (school type, and awareness of EPA IAQ Tools for Schools), and portable and traditional classrooms were not significantly different. However, portables and traditional classrooms were significantly different for the percent of time that the room was below 20EC (68EF). The percent of time that the portables had less than 20EC (68EF) temperatures was larger (by about 10%) than for the traditional classrooms.

Specially-Selected Schools

Fourteen schools were specially selected into the Phase II sample based on their Phase I results (high complaints of environmental problems or high formaldehyde levels). The Phase II formaldehyde levels for the classrooms at these schools appeared to match those estimated for the total population. CO_2 levels appeared to be somewhat lower, on average, for the classrooms in the specially-selected schools, as contrasted with those in the general population. On the other hand, moisture-related problems (musty odors, mold areas) were more frequently reported in these classrooms than in the general population of classrooms.

Conclusions

This is the largest, most comprehensive study of indoor environmental quality in California schools to date. The field effort began in October only weeks after the tragedy of September 11th. This event brought about changes to school procedures for clearing non-teacher, staff and students so that they could enter the building. This included some schools requiring finger printing of the technicians, and careful observance of what the technicians were doing as they brought in the equipment and set it up in the classrooms. Furthermore, it delayed gaining approval from the school authorities, in several cases.

Nevertheless, the resulting data from the 67 participating schools represent the IEQ conditions in portable classrooms (and traditional classrooms with less precision) across the state in the 2001-02 school year. Over 4 % of the schools in California were estimated to have more than 30 portable classrooms in school year 2001-2002. Also, an estimated 18.5% of the schools reported that they did not maintain HVAC maintenance records, as required, and another 22.8% were unsure if logs were kept.

There were a number of general classroom characteristics found to be significantly different between portable and traditional classrooms such as age (portables were newer) and construction material of the rooms. Also, similar to Phase I, there were a number of complaints from teachers from traditional classrooms as well as teachers from portable classrooms.

There were many study results indicating that there are Indoor Environmental Quality problems in both types of classrooms. For example, in all cases where there are standards or guidelines by which to judge the IEQ (such as noise, light, temperature, relative humidity, CO_2 and formaldehyde), there were some exceedances. Study data are available for further analysis, interpretation, and development of remedial actions.

Phase II provided measurement and observational information in greater detail than was obtained from Phase I. The data base provides a robust basis for statistical inferences regarding the population of schools with portable classrooms because response rates and data completeness were quite good for most analytes and questionnaire items. The exceptions were relatively poor data completeness for HOBO data regarding on/off cycles of HVAC units, CO data, and outdoor relative humidity data.

Most types of environmental complaints (roof leaks, air quality/odor, mold, temperature, noise) were reported more often for portable classrooms; an exception was plumbing leaks, which were more common in traditional classrooms. Pest related problems seemed to be about the same in portable and traditional classrooms.

Analysis of field blank samples, control samples, and duplicate samples revealed that analyte recovery and precision were reasonably good for most analytes. Hence, the quality control samples verified that the environmental measurement and laboratory data quality were satisfactory.

With respect to the HVAC characteristics, there were a number of significant differences between portable and traditional classrooms. Those related to <u>structure</u> include: physical location of unit (portables more wall units), type of fuel (electricity), type of unit (heat pump), and accessibility (better for portables). For those characteristics with <u>potential impact on environmental quality</u>, air filter dirt loading was lower in portables, and portables generally had more tightly fitting filters. HVAC filters in portable classrooms showed a higher percentage of mildew or mold, dirtier condensate drain pans, clogged drains, and standing water. Also, teachers were more likely to turn off the HVAC system due to high noise levels in portable classrooms. The air flow measurements in traditional and portable classrooms were not significantly different at the 5% level; however, outdoor air flow (cfm/ft^2) was significantly higher for portable classrooms at the 10% level.

The mean light intensity measured in the traditional classrooms was significantly higher than that measured in the portable classrooms. However, a small percentage of both portable and traditional classrooms did not meet IESNA light guidelines for high-contrast materials, and approximately one-third of both portables and traditionals did not meet the IESNA light guidelines for low-contrast materials, indicating inadequate lighting in both types of classrooms.

All classrooms exceeded the new ANSI acoustic standard for classroom noise levels (35 dBA), and a substantial percentage of both portable and traditional classrooms exceeded outdoor noise limits (45 and 55 dBA) set by some California communities. Noise levels measured in both types of classrooms were not statistically different. However, the teachers in portable classrooms were more likely to turn off the HVAC unit due to noise. This noise effect in portable classrooms was supported in the statistical modeling.

Temperature levels were significantly different, with some portable classrooms experiencing levels much cooler than ASHRAE comfort standards and some traditional classrooms experiencing levels notably warmer than ASHRAE comfort standards. Portables also had RH measurements above 60% more of the time than traditional classrooms; such levels are not only uncomfortable, but can lead to increased moisture and mold problems, increased dust mite populations (allergy and asthma triggers), and other problems.

Indoor formaldehyde air concentrations in Phase II were lower than those in Phase I; this was largely due to the many differences in procedures and timing of the two data collections. However, indoor levels are routinely higher than outdoor levels, and average formaldehyde levels are likely to fall between the Phase I and Phase II measurements. Thus, most classrooms exceed health guidelines for chronic effects, and a substantial percentage exceed guidelines designed to address acute effects. Other aldehydes and VOCs have not yet been examined relative to health-based guidelines, but indoor levels generally exceeded outdoor levels (similar to results in other studies), indicating the presence of indoor sources that may need to be addressed.

Airborne pollens and spores (primarily fungi) were found at higher levels outdoors than indoors, as expected. Typically indoor levels of fungi are elevated primarily in cases of extreme mold or biological contamination. However, classroom wall, floor, and ceiling moisture measurements indicated excess moisture in building materials in about 17% of the classrooms, indicating potential mold problems in those locations. Traditional classrooms had excess wall, floor, and ceiling moisture more often than portables, but portables were reported to experience roof leaks more often, and over two-thirds of the teachers in portables reported musty odors at times.

Pesticide residues were found in all floor dust samples, indicating the widespread use of a variety of different products in or near classrooms. Six pesticides were detected in over 80% of the rooms, with esfenvalerate (a common insecticide) showing the highest concentration and loading levels. Some of the pesticides are persistent chemicals, lasting for years, while other have an environmental lifetime lasting just weeks; thus, some of the pesticides were likely applied just a week or two prior to the sampling period at some schools in 2001-2002.

Similarly, 15 of the 18 metals analyzed for were detected in the floor dust samples. Some, such as arsenic, were detected at higher levels in portables, while others, like lead, were higher in traditional classrooms. Some of the metals are known to have neurological or carcinogenic effects. Most of the 16 PAHs studied (some of which are also known or suspected carcinogens) also were found in over 80% of the classrooms, but the loading levels were low. Most were found at higher levels in the portable classrooms.

Some contaminants in dust, such as pesticides, can be ingested or absorbed through the skin, as well as inhaled, making them undesirable in the floor dust of classrooms, especially those used for younger children who spend more time on the floor.

Dog and cat allergens were found commonly in floor dust. Dust mite allergens and cockroach allergens were found much less often.

1. INTRODUCTION

The California Air Resources Board (ARB) and the California Department of Health Services (DHS) provided funding as well as in-kind services and equipment to address indoor environmental concerns regarding the use of portable classrooms by public schools in California. These concerns have included problems associated with indoor concentrations of formaldehyde and other volatile organic compounds (VOCs), carbon monoxide (CO) and other combustion products, microbial growth, odors, and excessive temperature and noise. Problems have been attributed to inadequate or deferred maintenance, poorly designed and noisy heating, ventilating and air conditioning (HVAC) systems, and the use of pollutant-emitting materials, products, or equipment in or near buildings (Bayer et al., 1998). Health symptoms reported in schools are similar to those that are reported in “sick buildings.” Of noted concern are asthma-like symptoms, since asthma is one of the upward trending respiratory diseases in the U.S.

The purpose of this study was to assess environmental conditions in California’s portable classrooms. The results will be used by ARB, DHS, and other stakeholders to assess the potential for adverse health impacts from environmental conditions and toxic pollutants that may be present in portable classrooms, and identify effective actions that can be taken to remedy or prevent any unhealthful conditions found.

To generate the required data, RTI International has conducted a two-phase study. Phase I was a mailed survey, and Phase II was an environmental assessment field study of a sample of portable and traditional classrooms. Results from the two phases of this study are presented in separate project reports. This is the second of these reports. It focuses on discussing the methods used for collecting the Phase II data, and presents the results from Phase II of the California Portable Classrooms Study.

1.1 Background

There are many reasons to study the school indoor environment. Children in California spend, on average, about 5.5 hours per day at school. A large percentage of that time is spent indoors (Robinson and Thomas, 1991; Jenkins et al., 1992; Phillips et al., 1991). Teachers and other school staff typically spend even more time in school buildings. While in these buildings, the children and staff may be exposed to a number of chemicals and biological materials. However, children are often more susceptible to health effects and, hence, more likely to be affected by indoor pollution. School buildings are, by design, densely populated, making the task of maintaining an acceptable indoor environmental quality more difficult than in many other types of buildings. Yet there have been few studies of the effects of classroom environmental conditions on the learning process.

Concerns regarding indoor environmental quality in California’s schools have risen recently as the demand for classrooms has resulted in increased use of portable classrooms. Portable classrooms are usually constructed with materials and HVAC systems different from those used in traditional classrooms (Bayer et al., 1998). Manufactured buildings may emit hundreds of chemicals from the particle board, plywood, fiberglass, carpets, glues and other materials used in their construction. Adding to potential problems and environmental factors influencing the physical classroom are the specific activities which may be ongoing during the day that could add to already significant “background” concentrations. For example, VOC emissions of arts and crafts materials can add to levels of 1,1,1-trichloroethylene, toluene, xylenes, and formaldehyde.

Limited information indicates that some indoor environmental conditions in portable classrooms potentially put children at risk of serious health impacts. It has been reported that 63% of a total of 144 school districts responding to a California survey have experienced health complaints that may be associated with the classroom environment. These problems were attributed to moisture, fungal contamination, poor ventilation, and maintenance issues (CASH, 1999). There has not been a systematic or comprehensive statewide survey or measurement of indoor environmental conditions in California schools.

1.2 Objectives of Phase II Report

The overarching research objective of the California Portable Classrooms study is to assess environmental conditions in California’s portable classrooms. To accomplish this ultimate objective, the following specific research objectives are addressed:

1. To characterize distributions of pollutants and environmental conditions by type of classroom, for indoor air, chemical concentrations in dust, and other environmental measures, such as light and noise.
2. To characterize indoor/outdoor air associations by type of classroom.
3. To characterize performance of HVAC systems.
4. To test for significant differences between portable and traditional classrooms regarding indoor air concentrations and concentrations of chemicals in dust.
5. To assess the effects of HVAC performance and other factors on indoor air concentrations of pollutants for each type of classroom.

This report presents the results from the environmental assessment of the schools selected for the study. The report includes discussion of methods of school and classroom selection, sample collection and analysis, field procedures and protocols, and questionnaires and other data collection forms that were used in the Phase II study. The remainder of this report is organized into the following sections: (2) materials and methods; (3) results and discussion; (4) summary and conclusions; and (5) recommendations.

2. MATERIALS AND METHODS

2.1 Development of Questionnaires and Other Data Collection Forms

Six questionnaires or data collection forms were developed by copying items from the Facilities and Teacher Questionnaires used in Phase I, and adapting pre-existing HVAC checklists. Additional input was received from environmental consultants, the California ARB, and the California DHS. Several revisions were made to the questionnaires and data collection forms until the content and flow were satisfactory to the sponsoring agencies. Copies of all the questionnaires and data collection forms are provided in Appendix A.

Questionnaires were developed with the intention of minimizing the number of questionnaires completed during each school visit while segregating items that required input from different respondents or visiting different sites (e.g., indoors and outdoors) to different questionnaires. The HVAC Assessment Checklist and School Characteristics and Consultation with Facilities and HVAC Managers (Part 2) Questionnaire contained columns for all three classrooms rather than just one, so that only one questionnaire of each type was needed for each school.

Facilities Questionnaire

The Facilities Questionnaire II was derived from the first four pages of the questionnaire used in Phase I of the study. The questionnaire's purpose was to obtain background information about the school, information about HVAC inspections and maintenance, and identify environmental conditions that may have caused complaints. It was completed by the school's facility manager.

Teacher Questionnaire

The Teacher Questionnaire II was compiled from several items of Teacher Questionnaire I, used during Phase I of the study. Like the previous questionnaire, Teacher Questionnaire II obtained general information about temperature, odors, cleanliness, and environmental conditions in the classroom.

Classroom Form

Each Classroom Form's purpose was to collect observational information about one of the three selected classrooms at each school. The questionnaire was developed upon the review of other indoor air quality questionnaires and after suggestions from environmental health consultants. It was completed by the field technicians.

HVAC Assessment Checklist and School Characteristics

The purpose of this checklist was to capture all the measurements obtained by the field technicians. Measurements for all three classrooms were captured on one questionnaire to eliminate the need for two additional questionnaires per school. The second half of the questionnaire contains observation-type questions that capture the characteristics of HVAC systems. The HVAC questions were obtained from other HVAC questionnaires and Facilities Questionnaire I, used during Phase I of the study.

Consultation with Facilities and HVAC Managers (Part 1)

This brief questionnaire was developed to capture background and historical information about the classrooms. Characteristics of all three classrooms were captured on each form; hence, there was need for only one questionnaire for each school. It was completed by the field technicians in consultation with the school's facility manager and/or HVAC technician.

Consultation with Facilities and HVAC Managers (Part 2)

This brief questionnaire was developed to capture general information about the school and its grounds. A table was also added to capture information on pesticide usage; including type and frequency for pesticides applied as well as who applied the pesticide. It was completed by the school's facility manager.

2.2 Development of Introductory Letters and Other Survey Materials

As discussed in Section 2.5, recruitment of districts and schools for participation in Phase II of the study began with mailing a letter to the Superintendents. This letter was developed from the letter to superintendents that was used in Phase I of the study. The letter provided information regarding the mandate for the study, described what schools participating in the study would be asked to do, and asked that the superintendent fax a letter of support to RTI. A copy of the letter to superintendents is provided in Appendix A.

Enclosed with the letter to the superintendents was a sample letter that the district could use as a template and fax to RTI to indicate their support for the study. A copy of this sample letter is provided in Appendix A.

The letter to the principal, requesting the school's participation, was based on the letter used in Phase I of the study. Like the letter to the superintendent, it provided information regarding the mandate for the study and described what schools participating in the study would be asked to do. In addition, the letter of endorsement from the superintendent was enclosed, if it was available, and, if it was not available, the letter noted that the superintendent had given verbal approval for the school to participate in the study. Both versions of the letter to the principal are provided in Appendix A.

2.3 Environmental Sampling and Analysis

2.3.1 Pre-testing of Methods

Testing the field data collection methods was a three step process: preparation and review of protocols, pre-pilot testing in one NC school, and pilot testing in two schools in CA. Development of methods, procedures and protocols was necessary so that the field team would have a clear and complete understanding of what would be required and the order for implementing the methods in the field. This step served to highlight what training was required before the methods could be used in the field. As RTI prepared for the study, field procedures for calibrating all instruments, the quality control procedures required to ensure that the instrumentation was working properly, and the field protocols required to maintain the integrity of the sample while handling, storing, and shipping samples to the laboratory for analysis were reviewed. Also during this process, the system for handling the samplers, samples, and field data sheets was developed. This system formed the basis for the data information shell, a computerized field operation system. This system provided information to the field technicians about what monitoring were required at each school, as discussed in Section 2.5.3. It also provided a check list and order of performance for each of the required activities at each school, together with the chain of custody and sample tracking sheets.

The monitors, procedures, and protocols (with the exception of the HVAC assessment) were tested in a pre-pilot study at an elementary school in traditional classrooms in Durham, NC. Because this phase of testing was a dress-rehearsal of the field logistics and methodology, the samples were not saved. The checklists used for this exercise had been adapted from forms used in the Texas Elementary School Indoor Air Study (Torres et al., 2002) and from the EPA's Tools for Schools Building Air Quality Questionnaire (www.epa.gov.iaq/schools). Subsequent to the actual pilot test in California, these checklists were discarded and replaced with completely redesigned forms, as described above in Section 2.1.

Following the pre-pilot, the pilot field study was conducted in the Sacramento area of California. The Air Resources Board provided RTI with several district names and contact persons to call about participating in the pilot study. RTI called five different school districts and received approval to conduct the pilot study at two schools, one elementary school and one high school.

A description of the sampling and analysis methods that were used in the field study are summarized in the following sections.

2.3.2 Sample Collection and Analysis Methods

Human Comfort. Human comfort is often strongly associated with temperature. Thermal comfort levels result from the interaction of temperature, relative humidity, air movement, clothing, activity level, and individual differences. From a measurement perspective, the first two, temperature and relative humidity, are the primary indicators of thermal comfort measured in the classrooms for this study. However, air movement data also were collected and are presented within the framework of ventilation. Maintaining appropriate levels of these factors can provide a relatively simple and inexpensive way to reduce environmental stressors in the classroom. Acceptable ranges of temperature and relative humidity during the summer and winter are available for comparison (ASHRAE Standard 55-1981).

Temperature and relative humidity were measured continuously with the Q-Trak instrument. (See www.tsi.com.)

Light. Classroom lighting was measured at 3 locations, one at a desk near a window, one at the center of the room, and one on the far side away from the windows, in each classroom. The quantity of light was measured in units of foot-candles (English) per lux-meter (metric). (See www.extech.com.) The unit displays light measurements with accuracy within 5%. This information was collected by a technician and recorded in the HVAC Assessment Checklist and School Characteristics CA PCS Phase II form described in Section 2.1.

Noise. Classroom noise was measured in the center of the room, 10 feet from the return register, and outside on the noisiest side of the room for each classroom and recorded by the technician onto the HVAC Assessment Checklist and School form. Noise readings were taken in an empty classroom with the HVAC on and off at break time or at the end of the day. Measurements were taken in the center of the classroom and one 10 feet away from the return register or in the noisy area of the room in each classroom. One reading was also taken outside of the classroom. Each measurement was taken both with the HVAC on and with it off. A simple sound level meter manufactured by Cirrus Research was used for this purpose which provided measurements in decibels (dB).

Moisture. Moisture measurements were made with a Delmhorst BD-8 Meter to determine the relative moisture content of materials. These moisture measurements are based on the principle of electric conductivity. Raw data were entered directly into the HVAC Assessment Checklist and Item B-5 of the School Characteristics Checklist. Readings were taken at six locations, all four walls plus the floor and ceiling. Moisture readings were taken in a location with mold or water stains, if present. Otherwise they were taken in the center of the wall or under windows.

Ventilation. The HVAC system includes all the heating, cooling, and ventilation equipment serving the classroom. The HVAC function and performance for each classroom were assessed through input from the facility manager and with measurements of air flow taken in the classrooms. The questionnaire and measurement aspects are discussed in Section 2.1.

Formaldehyde and Other Aldehydes. Formaldehyde samples were collected in each of the classrooms and outdoors. Aldehydes were collected by passing air through commercially available 2,4-dinitrophenylhydrazine (DNPH) coated silica gel cartridges. A battery powered low flow, constant flow air pump pulled air through the sampling cartridge. Potential air interferents were removed from the sampled air using a potassium iodide scrubber at the DNPH cartridge inlet. Samples were collected from approximately 8:00 a.m. until around 4:00 p.m. in each of the schools. The cartridges were stored on ice and shipped to RTI for analysis. After extraction with acetonitrile, the sample extract was analyzed by high pressure liquid chromatography (HPLC) with UV detection. The detection limit of this method is 1.4 $\mu g/m^3$. The list of target aldehydes and other carbonyls is shown in Table 2-1.

Formaldehyde is the only compound that was measured in classrooms in both Phase I and Phase II of this study. Differences in the data collection methods and protocols must be considered when comparing the results. In Phase I, formaldehyde samples were collected over a 7- to 10-day period using a passive PF-1 sampling tube manufactured by Air Quality Research (AQR). Integrated average formaldehyde concentrations were determined by AQR using NIOSH standard laboratory reference method 3500. As described above, an active integrated sampling method, DNPH, was used in Phase II to monitor classrooms for the 6- to 8-hour period of time when classes were in session. Therefore, comparison of formaldehyde concentrations between Phase I and Phase II of this study must account for the following differences in methodology:

Phase I concentrations were integrated over 7 to 10 days, whereas Phase II concentrations were integrated over 6 to 8 hours when classes were in session.
Phase I concentrations included nighttime and weekend hours when classrooms may have been closed and the schools' HVAC systems may have been off, whereas Phase II samples were collected entirely during the day when classes were in session.

Phase I samples were collected mostly in the spring, whereas Phase II samples were collected in the fall and winter. (Formaldehyde emissions are temperature- and humidity-dependent.) Because the Phase II sample size is much smaller (199 classrooms with formaldehyde data versus 911 classrooms in Phase I), extreme values are less likely to be observed in Phase II. The passive sampler method used in Phase I is a screening method. It is not intended to be highly accurate and sensitive; passive formaldehyde monitor concentrations typically are within 20 to 30% of active monitor concentrations.

Table 2-1. List of Target Aldehydes and Other Carbonyls

formaldehyde acetaldehyde acetone* acrolein** benzaldehyde	Isovaleraldehyde n-butraldehyde crotonaldehyde hexaldehyde 2,5-dimethylbenzaldehyde	propionaldehyde o-tolualdehyde m-tolualdehyde p-tolualdehyde valeraldehyde

*unable to quantify due to variable background levels
**unable to quantify due to interferences in signal

VOCs. Volatile organic compounds (VOCs) were collected on Carbotrap 400 multisorbent tubes with Dupont P-125 constant flow samplers. Four to 6 L of air was pulled through each tube. This air flow provided a detection limit of approximately 2 Fg/m^3. The tubes were stored on ice and returned to RTI for analysis by thermal desorption/GC/MS. Analysis was by full scan GC/MS with processing for the specific target list shown in the Table 2-2.

Table 2-2. List of Target VOCs

benzene toluene m,p-xylenes and o-xylene	1,1,1-trichloroethane tetrachloroethylene carbon tetrachloride	chloroform butadiene* ethylbenzene

* unable to quantify

2.3.3 Methods for Continuous Measurements

Carbon Monoxide, Carbon Dioxide, Temperature, and Relative Humidity. For the pilot study, carbon monoxide (CO), temperature (T) and relative humidity (RH) were measured continuously with two instruments. These instruments were set up in each classroom and at an outside location to provide measurements for an assessment of both indoor and outdoor sources, as well as ventilation within a classroom. CO was measured using Draeger Model 190 CO monitors. Results were stored and reported as one hour average and peak CO concentrations. Temperature and relative humidity were collected using a HOBO data logging system. To improve field operations, RTI replaced these two instruments with a single Q-Trak instrument after the pilot study. This eliminated one piece of equipment at each monitoring location at each school, making it easier for the field technicians. In addition to CO, temperature, and relative humidity, the Q-Trak also provided continuous measurements of carbon dioxide (CO_2). The Q-Trak used a non-dispersive infrared (NDIR) sensor for the CO_2 measurement and an electro-chemical sensor for CO.

Real-Time Particle Counts. RTI used a battery-operated Met One Portable Airborne Particle Counter to measure real-time particle counts. This system provides counts of particles at various sizes, including: > 0.5 µm, >2.5 µm, and >10 µm. By subtraction of the counts, particle counts are available for the fine and course fractions that are usually referred to in EPA standards. These instruments were placed in each classroom and outdoors at one location at each school.

Special Functions. A HOBO data logger with an electric field sensor (open/closed) was installed on each HVAC unit to record when the unit was running.

2.3.4 Floor Dust Collection and Analysis

Floor Dust for Biological and Chemical Analysis. Floor dust samples were collected in each classroom for animal and arthropod allergen analysis by California Department of Health Services (DHS). This dust was also analyzed for pesticides, metals, and PAHs. The dust was collected using the Data Vac 2 vacuum cleaner that had been previously used for the EPA's National Human Exposure Assessment Survey (Pellizzari et al., 1999).

Before RTI made the final decision to use the Data Vac 2, a side-by-side comparison with the High Volume Small Surface Sampler (HVS3), developed by Envirometrics, Inc., was performed at the pre-pilot phase in NC. In the pre-pilot study, the major operational characteristics were compared. The following information was obtain from this comparison: (1) the HVS3 is much more difficult to operate — it is much heavier and subject to changes in settings to obtain the proper suction and readings; (2) cleaning the HVS3 between classrooms took about 1 hour**,** compared to less than 5 minutes for the Data Vac 2; and (3) the Data Vac 2 collected more dust than the HVS3 over the same area. Because collecting a sample with enough dust for numerous analyses was an important goal, RTI verified this last observation in other locations to strengthen the case for using the Data Vac 2. Table 2-3 presents these results which indicated that using the Data Vac 2 would be expected to provide more sampled mass than the HVS3. Accordingly, RTI and ARB decided to use only the Data Vac 2 in the pilot study and subsequently in the main field study.

Table 2-3. Comparison of Dust Mass (g) Collected by the HVS3 and the Data Vac Samplers from a Side By Side Area of 1.49 m^2

Location	HVS3		Data-Vac	
	mass(g)	g dust/m^2	mass(g)	g dust/m^2
Location 1	1.9965	1.34	3.9729	2.67
Location 2	0.9702	0.65	2.8288	1.90
Location 3	0.0536	0.04	0.223	0.15
Location 4	0.1046	0.07	1.6205	1.09

The collected dust samples were shipped to RTI where they were sieved to remove unwanted debris and large (>500 micron) particles. To reduce analytical costs, equal portions of the dust collected from the two portable classrooms were combined for each school to provide the total mass required for the specific analysis. For metals, 50 mg of dust was used. For pesticides and PAHs, a total of 200 mg was used. Approximately 500 mg of the sieved dust was sent to the California Department of Health Services (DHS) for analysis for arthropod and animal allergens. The remainder of the sample, if any, was stored in freezers at -20°C at RTI.

The chemical species, elements, and allergens to be analyzed were reviewed and recommended by an advisory panel of State scientists with expertise in this area of measurement science. The analytes were chosen based on their health effects, their prevalence in California, their detectability, and the cost of analyses.

Analysis of Dust for the Determination of the House Dust Mite Allergens. The 500 mg sieved dust sample was sent to the DHS laboratory. A saline buffer was added to the sample, and any dust mite allergens present (>99% recovery) were extracted from the dust into the buffer solution. Analysis of the solution was by the ELISA method for mite allergens Der p 1 and Der f 1 in the sample liquid extracts, with quantification by UV spectrophotometer.

Analysis of Classroom Floor Dust for Trace Metals. The analysis method used by RTI for the dust samples was Inductively-Coupled Plasma Mass Spectrometry (ICP-MS). This method provides a multi-elemental determination. Samples were received and prepared in a metal-free Class 100 sample preparation laboratory. Sample material in solution was introduced into the ICP-MS by pneumatic nebulization into a radio frequency argon plasma. The ions are extracted from the plasma and separated on the basis of their mass-to-charge ratio by a quadrupole mass spectrometer. Table 2-4 provides the list of analytes looked for in the dust samples.

Table 2-4. List of Target Metals

Aluminum	Arsenic	Cadmium	Cesium
Chromium	Cobalt	Copper	Iron
Lead	Magnesium	Manganese	Nickel
Paladium	Selenium	Strontium	Titanium
Vanadium	Zinc		

Analysis of Dust for Pesticides and PAHs. The analysis method used for the dust samples was GC/MS in the selected ion monitoring mode (SIM). The sample extract was injected into the GC/MS system where analytes were separated on a fused silica capillary column. The compounds were identified based on chromatographic retention time of at least two representative mass fragment ions by comparison to standard solutions analyzed under identical conditions. One ion (a primary ion) was used for quantitation of a given compound. Quantitation was carried out by the method of internal standards by utilizing the areas of the analytes and internal standards to determine relative response factors for each specific analyte of interest. Table 2-5 provides the target list of pesticides and PAHs for this study.

Table 2-5. Target List of Pesticides and PAHs

PESTICIDES			PAHs
Chlorpyrifos	Lindane	Simazine*	Acenaphthalene
Diazinon	Imidacloprid*	DDVP*	Acenaphthylene
cis-Permethrin	Propetamphos	Naled*	Anthracene
trans-Permethrin	Bifenthrin	Oxadiazon*	Benzo(a)anthracene
Cypermethrin	Deltamethrin	Oryzalin*	Benzo(a)pyrene
Malathion	Pyrethrins	Prodiamine*	Benzo(b)fluoranthene
Cyfluthrin	Pendimethalin	PCNB*	Benzo(g,h,i)perylene
lamda-Cyhalothrin	Chlorothalonil*	Fenoxycarb*	Benzo(k)fluoranthene
Diuron*	Esfenvalerate	Bendiocarb*	Chrysene
ortho-Phenylphenol	Carbaryl*	Dacthal*	Dibenz[a,h]anthracene
Propoxur	Piperonyl butoxide	Dicofol*	Fluoranthene
Tralomethrin	Resmethrin	Dichlorvos*	Fluorene
DDE	Captan*		Indeno[1,2,3-cd]pyrene
Dieldrin			Naphthalene
			Perylene
			Phenanthrene
			Pyrene

* unable to quantify

Culturable Airborne Microorganisms. RTI also collected surface samples using cotton swabs and Mattsen-Garvin (M-G) bioaerosol samples to be analyzed for fungi and other microbial growth. However, to reduce costs, these samples were only collected in "specially-selected schools" (see Section 2.4.1). M-G samples were collected for 15 minutes, both indoors in the three classrooms and outdoors at the one site. Cotton swab samples were only collected in areas where microbiological growth could be visually determined.

The M-G slit-to-agar volumetric bioaerosol sampler selectively measures culturable airborne bacteria and fungi. The slit-to-agar sampler allows particles in a measured volume of air to impact upon microbiological growth medium in rotating petri dishes that are then incubated at appropriate temperatures. Culturable bacteria and mold particles grow into visible colonies that are counted and identified. Final results obtained with the sampler provide a measure or concentration of viable, culturable airborne bacteria or fungi expressed in colony forming units per cubic meter of air (CFU/m^3).

The procedure used for collection of environmental swabs for microbiological analysis required a sample of dust or debris collected from an environmental surface using a pre-sterilized, dry cotton swab. The person collecting the samples broke off the swab and discarded the portion that came into contact with bare hands while collecting the sample. The portion of the swab with the sample was then placed into a sterile container and returned to RTI for analysis.

Direct Examination for Pollens and Spores and Identification. An Allergenco sampler was used to collect airborne biological agents impacted onto a glass slide. The slide was then read by Aerotech Laboratories, Inc., using a 400-1500 X brightfield microscope. Using this method, all fungal spores were enumerated, including non-viable spores. The targeted fungal species are listed in Table 2-6. Slides were collected in each of the sampled classrooms, plus at one outdoor location.

Table 2-6. List of Target Pollens and Spores Species

Alternaria Amerospores Arthrinium Ascospores Aspergillus/ Penicillium-like Aureobasidium	Basidiospores Bipolaris/ Dreschlera Botrytis Chaetomium Cladosporium Curvularia	Epicoccum Fusarium Memnoniella Nigrospora Oidium/Peronospora Pithomyces/Ulocladium	Rusts Smuts/Myxomycetes Stachybotrys Stemphylium Torula Unidentified Conidia
Mycelial Fragments	Pollen Count	Total Fungal Spores	

Videotaping Methodology for Documentation of Monitoring Site Environments. Videotaping was used to record environmental settings and monitoring equipment in the classrooms, main school facility, and outdoor environments. For each classroom undergoing monitoring, the field technician(s) attempted to record the layout of the room, the locations of samples collected and HVAC systems, and any other observations deemed important by the field staff for assessing the environmental conditions of the classroom. The field technician began recording after all monitors had been set up. The technician verbally described the setting and monitoring locations while taping with the video recorder, being careful not to include teachers, children, or any other confidential information in the video, such as the name of the school.

2.4 Statistical Sampling Design

2.4.1 Selection of Sample Schools

The sampling frame for Phase I of the PCS was the California Public School Directory 2000, which was published by the California Department of Education Press. CA DHS staff sorted this frame by the county/district/school (CDS) code and selected a 1-in-7 systematic sample from the sorted frame, which resulted in an initial sample of 1,216 schools. Hence, the Phase I sample was implicitly stratified by county and district, ensuring representation of these geographic areas proportionate to the number of public schools in each area.

DHS then conducted a preliminary survey of the school districts with at least one school in this sample and identified 177 schools that did not have any portable classrooms. These schools were deleted from further consideration for the PCS, leaving 1,039 schools that appeared to be eligible for Phase I of the PCS. From these 1,039 eligible schools, 1,000 were randomly selected for Phase I of the PCS.

All of the ineligible schools in the sample (those with no portable classrooms) were identified during Phase I data collection, including telephone follow-up of non-responding schools. This process determined that 48 of the 1,000 schools in the Phase I sample had no portable classrooms. Hence, the CA PCS Phase I sample of 1,000 schools included 952 eligible sample schools (with portable classrooms).

The sample of schools selected for Phase II of the CA PCS was a stratified random sample of 86 of the 952 eligible schools in the Phase I sample. As shown in Table 2-7, 938 eligible sample schools were stratified by:

- *School level:* Schools for which the highest level of offering (based on the CA Public School Directory 2000) was less than seventh grade were defined to be elementary schools.
- *Location:* Counties were partitioned into Northern and Southern California based on temperature and rainfall differences and the results of an earlier formaldehyde study in mobile homes (Liu et al., 1986). As shown in Figure 2-1, the southern boundary of Northern California was defined to be the southern boundaries of Monterey, Fresno, and Mono Counties.
- *Urbanicity:* Schools for which POP_STATUS from the CA Public School Directory was 5-7 (large town, small town, or rural) were classified as rural.
- *Potential IEQ Problem:* Schools that satisfied at least one of the following conditions based on their Phase I data were defined to have a potential IEQ problem (Problem=Yes):

    - Had at least one portable classroom in the upper 25% of the distribution of Phase I formaldehyde concentrations in portable classrooms
    - Had at least one portable classroom with poor or very poor overall environmental quality reported by a teacher (TQ37)
    - Had 2 or more portable classrooms or 5 or more traditional classrooms with a roof leak, plumbing leak or flood, or mold problem in the past year reported by the Facility Manager (FQ25).

  Other schools that participated in Phase I were classified as not having a potential IEQ problem (Problem=No), and schools that did not participate in Phase I were classified as not knowing whether or not they had a potential IEQ problem (Problem=Don’t Know).

The 14 schools in the Phase I sample that appeared to have the greatest potential for indoor environmental quality (IEQ) problems were all included in the Phase II sample and are referred to as the “specially-selected schools.” The 14 specially-selected schools comprise Stratum 1 of the Phase II sample and were those schools whose Phase I data satisfied two or more of the following conditions:

- Had at least one portable classroom with one of the 20 highest formaldehyde concentrations among the portable classrooms with Phase I data (over 89 ppb)
- Had at least one portable classroom with visible mold reported by a teacher (TQ32)
- Had at least one portable classroom with very poor overall environmental quality reported by a teacher (TQ37)
- Had 5 or more classrooms (portable or traditional) with a mold problem in the past year reported by the Facility Manager (FQ25).

Figure 2-1. Definition of Northern and Southern California for the Portable Classrooms Study

Of the 14 specially-selected schools, 13 had visible mold reported by a teacher, 12 had very poor overall environmental quality reported by a teacher, four had 5 or more classrooms with a mold problem reported by the Facility Manager, and one had classrooms with formaldehyde concentrations over 89 ppb. However, the formaldehyde concentrations were over 70 ppb for all three sample classrooms in the latter school, and they were over 35 ppb for all three sample classrooms in another school.

Although the Phase II sample schools were selected using stratified random sampling, all strata were sampled at approximately the same rate, except for the 14 specially-selected schools that were selected with certainty. The purpose of the stratification was to ensure the representativeness of the sample, rather than to over-represent any particular segment of the population. The schools in each stratum were randomly ordered. We first contacted the district superintendent (including local districts in the Los Angeles Unified School District) and then the school principal (as discussed in Section 2.5) for each sample school. For each stratum, we contacted only enough superintendents and principals to achieve the target number of participating schools shown in Table 2-7.

2.4.2 Selection of Schools for the VOC Subsample

Half the schools in each stratum were randomly selected to have indoor and outdoor VOC samples collected. For each of the 15 strata, the first school that agreed to participate was randomly assigned to either have, or not have, VOC samples collected. The remainder of the participating schools in each stratum were then assigned to the VOC sample in the order in which they agreed to participate so that the sample alternated between schools that were and were not included in the VOC subsample.

2.4.3 Selection of Sample Classrooms

From each of the sample schools that agreed to participate, we obtained a site map that identified the school's portable and traditional classrooms. We randomly selected two portable classrooms and one traditional classroom as the primary sample, except for schools that had only one portable classroom. For them, we randomly selected the one portable classroom and two traditional classrooms. For each school, we also randomly selected the same number of portable and traditional classrooms as a backup sample to be used whenever the classroom teacher refused or the classroom was not in use on the day scheduled for monitoring.

The procedures used to select sample classrooms for the 14 specially-selected schools retained from the Phase I sample were different from those used for the other Phase II sample schools. For the 14 specially-selected schools, we attempted to monitor the same classrooms that were monitored in Phase I. Thirteen of these schools agreed to participate in Phase II, and exceptions were necessary for one classroom in each of three schools: one in which the portable classroom was no longer located at the school (another portable classroom was randomly selected), one in which the traditional classroom was no longer being used as a classroom (another traditional classroom was randomly selected), and one in which three portable classrooms were selected in Phase I (one traditional classroom was randomly selected as a substitute for one of the portable classrooms for Phase II). The other 36 classrooms monitored in the 13 participating specially-selected schools were the same classrooms monitored during Phase I.

Table 2-7. Phase II Stratum Sample Sizes and Numbers of Target Schools

Stratum	School Level	School Location	Urbanicity	IEQ Problem	Frame Count	Sample Size	Target Respondents
1	Specially-selected Schools				14	14	14
2	Elementary	North	Rural	NA	31	2	2
3	Elementary	North	Not Rural	DK	123	8	7
4	Elementary	North	Not Rural	No	40	3	3
5	Elementary	North	Not Rural	Yes	37	2	2
6	Elementary	South	Rural	NA	22	2	2
7	Elementary	South	Not Rural	DK	175	14	10
8	Elementary	South	Not Rural	No	65	6	4
9	Elementary	South	Not Rural	Yes	62	4	4
10	Not Elementary	North	Rural	NA	63	4	4
11	Not Elementary	North	Not Rural	NA	128	11	7
12	Not Elementary	South	Rural	NA	21	2	1
13	Not Elementary	South	Not Rural	DK	103	10	7
14	Not Elementary	South	Not Rural	No	36	2	2
15	Not Elementary	South	Not Rural	Yes	32	2	2
Total					952	86	71

Note: DK = don't know and NA = not applicable.

2.5 Data Collection

2.5.1 Human Subjects Approval

Research Triangle Institute's Institutional Review Board (IRB) reviewed and approved the data collection forms and procedures for both Phase I and Phase II of the CA Portable Classrooms Study. The Phase I procedures were approved in March 19, 2001 and the Phase II procedures were approved on September 14, 2001. Toll-free phone numbers were provided on the study materials if the respondents had any questions about their rights as survey respondents. A handful of teachers called the IRB contact and inquired about the study results. Other project staff followed-up with these inquiries in a timely and appropriate manner. RTI's IRB followed the study closely, hence, we can be sure that the study conformed to strict government guidelines for obtaining informed consent, and protecting human rights of all the study participants.

2.5.2 Recruiting Districts

In August 2001, RTI sent advance packages about the study via Federal Express to superintendents in Priority 1 and 2 districts (those definitely needed and those likely to be needed as replacements for nonrespondents) requesting permission to contact school principals of selected schools. The advance package included a letter of endorsement from the California Superintendent of Public Instruction, a letter from the RTI Project Director, a study brochure, a list of sampled schools for the district, and an example of a district letter of support. Within several days of the Federal Express mailing, RTI recruiters made follow-up calls to all Priority 1 district superintendents. This call was placed to obtain permission to contact selected schools' principals about the study and to identify a district contact person for the study.

2.5.3 Recruiting and Scheduling Schools

Similar to the advance package sent to districts, an advance package about the study was sent via Federal Express to school principals requesting permission to conduct the study at the school. These advance packages to principals included a letter from the California Superintendent of Public Instruction, a letter from the RTI Project Director, a study brochure, and a letter of support from the district (when provided). Once again, within several days RTI recruiters made follow-up calls to school principals to obtain permission from the school principal or designated contact person to conduct the site visit for the study. As needed, RTI replaced refusing or ineligible schools by contacting the next available school on the randomly ordered sample stratum list. If the district had not already been contacted (was not a Priority 1 or 2 district), the district was contacted first.

The RTI recruiter completed the following tasks with the school contact person: received a copy of the school site map via facsimile; identified portable and traditional classrooms on the map; identified the facilities manager; and received a facsimile of the school calendar. The RTI recruiter then selected the classrooms to be monitored at the school and sent this information and other pertinent site information via email to the RTI scheduler who then contacted the school to secure the date of the site visit and answer any final concerns or questions. One week prior to the site visit, RTI sent a confirmation letter to the school and the Facilities Questionnaire to the designated facilities manager.

Once site visits were completed, RTI sent thank you letters and participation checks of $100 to participating schools.

2.5.4 Field Data Collection Procedures

The field team visited each school on the date established during recruitment. The field team consisted of a trained HVAC technician and two environmental field technicians. They usually arrived at the school 30 minutes before the classes started, sometimes earlier, which meant that they sometimes arrived before 7:00 a.m. After arriving at the school and checking in with the principal's office, they began setting up the equipment in the three pre-selected classrooms, usually two portable classrooms and one traditional classroom.

They brought a single box to each sample classroom. It contained one each of the following instruments: Met One Particle Counter, Q-Trak, aldehyde sampler and pump, and, if the school was selected to have VOC sampling, a VOC sampler and pump. A similar box was taken to one location outside to set up for the outdoor measurements. These instruments operated continuously during the school day and until the instruments were shut down at the end of the school day, usually around 4:00 p.m. Also, a HOBO data logger was placed on the HVAC unit to record when the unit was on and off.

Throughout the day, the other measurements were taken, including the lighting, noise, air flow, microbiological samples (Allergenco), and wall moisture. If the school was a "specially – selected" school (see Section 2.4.1), then a 15-minute Mattsen-Garvin sample and microbial swab samples were taken during the lunch period when the room was vacant. Also during the day, the data collection forms were filled out. At the end of the day, after the children had left, the dust samples were collected and the videos were taken. Table 2-8 summarizes the types of measurements taken at each school.

2.6 Monitoring Receipt of Questionnaires and Data Collection Forms

Several procedures were implemented to monitor questionnaires coming from the field and follow-up on outstanding questionnaires. All questionnaires and study materials for a school were collected and returned in an accordion folder labeled with the school name and ID. Upon receipt, the questionnaires and study materials were distributed to the appropriate staff. A Chain of Custody Checklist and a Survey Control System were used to track incoming questionnaires and identify outstanding or missing questionnaires. After missing questionnaires were identified, telephone follow-up and re-mailings were conducted to increase the response rate.

2.6.1 Chain of Custody

The field technician was asked to complete a Chain of Custody (COC) Checklist as questionnaires were completed in the field. The checklist provided columns for each questionnaire a school was asked to complete, and check boxes for the questionnaires. A "comments"column provided additional information, such as if the teacher refused, if the teacher or facility manager said they would mail the questionnaire to RTI, etc. The checklist was used to update the control system when questionnaires were received.

2.6.2 Control System

A Microsoft Access survey control system was designed to monitor incoming and outstanding questionnaires. Once a questionnaire was received, project staff used the COC checklist to update the corresponding questionnaire boxes in the control system. The "comments" field of the database was used for describing phone conversations and results. The control system easily identified missing questionnaires.

2.6.3 Telephone Follow-up

An experienced telephone interviewer conducted telephone follow-up of questionnaires that were identified as missing by the control system. A contact sheet was used to summarize all the contact information necessary to conduct telephone follow-up. The contact sheet also contained the classrooms selected for sampling and any backups that could be used as alternatives. The classroom sampling information on the contact sheet was effective in the event a questionnaire had to be mailed to the attention of a teacher in a particular classroom. After reviewing the "missing" questionnaires and contact information for those schools with outstanding questionnaires, the telephone interviewer prompted schools about missing questionnaires. As telephone prompts were made, a telephone script was followed and adjusted, as necessary. Notes from each call were added to the "comments" field of the control system.

Two common telephone follow-up situations and their resolutions are described below.

Table 2-8. Types of Data Collected

What was collected?	Where was it collected?	When was it collected?
Temperature and relative humidity	Each classroom and outside	Throughout the day
Light	Each classroom	5 minutes/classroom when no students present, usually mid-day.
Noise	Each classroom	When no students were present, usually mid-day.
Moisture	Each classroom; inside walls	5 min/classroom when no students present, usually mid-day.
Ventilation	Each classroom and outside	5 min/classroom at each vent when no students present.
Instrument panel $ VOCs, Aldehydes $ Particle Counts $ CO, CO_2, T, RH	Each classroom and outside	Throughout the day
HVAC status	Outside HVAC unit	Throughout the day
Microbiologicals (Allergenco)	Each classroom and outside	5 min/classroom during the day.
Culturable biologicals	Each classroom and outside for "specially-selected" schools	15 min during the lunch break
Classroom floor dust	Each classroom	At the end of the day
Video	Each classroom and outside	At the end of the day
Data collection forms	School and classroom	During the day and some mailed to RTI later by the FM

Difficulty Contacting Principal or Facility Manager - If the appropriate person was not reached, up to four attempts were subsequently made at different times of the day and/or days of the week. If all telephone prompts were unsuccessful, the school or district's fax number was obtained, and the appropriate school or district staff person was prompted by a fax.

Lost Questionnaire – The principal or facility manager was asked if he or she would complete another questionnaire. If agreeable, another questionnaire(s) was mailed to the principal or facility manager.

As a result of telephone follow-up and re-mailing questionnaires to non-respondents, a 94% response rate was achieved. RTI received 627 out of a possible 670 questionnaires from field data collection. Most of the outstanding questionnaires (41 of 43) were a result of non-response, although two were the result of refusal by one teacher.

2.7 Data Processing

Once questionnaires were accounted for in the control system, editing, keying, and scanning activities began. Every questionnaire (scannable and pencil and paper instruments) went through a preliminary edit to ensure that IDs and ID-Classroom Number linkage was accurate. Upon completion of this preliminary edit, questionnaires were separated into scannable and pencil and paper instruments and passed along to the appropriate data processing staff.

2.7.1 Processing Scannable Instruments

Programmers tested the Teacher and Facilities Questionnaires to ensure that the Teleform program captured marks on the data collection instruments. Once the programmer was assured that all marks were captured on the "test" questionnaires, the remainder of the questionnaires were scanned. During the scanning process, the Teleform reader identified problems, such as missing entries in key fields, and flagged them for resolution. Images from the scanned questionnaires were copied to an electronic file for error resolution.

2.7.2 Processing Instruments for Data Entry

The pencil and paper questionnaires first were subjected to manual editing based on written specifications. A data entry program was then used to capture all items in the instrument.

Data Editing

Edit specifications were developed for the four pencil and paper questionnaires. Codes and ranges in the specifications were consistent with the questionnaires. Editors were trained by reading the edit specifications as they reviewed completed questionnaires.

Edit problems were minimal and consisted of key items that were left blank or others that were out of range. Minimal contact with school and facilities staff about edit problems was necessary.

One hundred percent quality control was performed on the first 5 questionnaires of each type before any data were keyed. Quality control on first five questionnaires yielded two errors in 20 questionnaires. This was considered "very good" given the number of items on two of the questionnaires (Classroom and HVAC). After data collection was complete, additional QC was performed on 10% of the questionnaires. This yielded two potential errors that occurred on five of the 29 forms reviewed. Edit errors identified during QC have been corrected in the dataset.

Data Entry

A codebook was developed prior to creation of the data entry program. The codebook was compared to questionnaire and edit specifications for accuracy. A user-friendly data entry program, based on the codebook, was then developed. The data entry program was tested prior to usage for valid ranges, text entries, and consistency codes. All data were double-keyed to ensure accuracy of data entry.

2.7.3 Preparation of School-level Analysis Files

The school-level Phase II questionnaire data consisted of responses to questionnaire items from two questionnaires (see Appendix A):

Facilities Questionnaire
Consultation with Facility and HVAC Managers (Part 2)

These data were stored in separate files and each file was processed separately. As a first step in preparing the data for analysis, a revised version of each file was created. This entailed the following basic steps:

1. Recoding of negative missing value codes to SAS[2] special missing value codes.
2. Recoding of "circle all that apply" responses to have response codes of 1 (yes) and 2 (no).
3. Review of variables designed as single-response items for which multiple responses were recorded to see if any should be recoded as multiple-response items.
4. Recoding and consistency checking of variables involved in skip patterns to create new combined variables that have appropriate response categories for all respondents (e.g., by adding a "not applicable" category).
5. Recoding (e.g., collapsing of categories) of variables to create new variables suitable for analysis (see Section 2.9).

To ensure accuracy of the recoded variables, cross tabulations of the original and recoded variates were generated and examined. In addition, steps 1 and 2 above were accomplished with specially written SAS macros.

The final school files were created by augmenting the appropriate adjusted school-level sampling weight to each record of the file (see Section 2.8). Initially, we had planned to merge the files to form a single school-level file. However, since nonresponse patterns differed for the two files, separate weights were needed for each file; consequently, to ensure that users would utilize the appropriate sampling weight in their analyses, we decided to maintain two separate analysis files:

[2] SAS is the registered trademark of SAS Institute, Inc., Cary, NC.

- The Facilities Questionnaire File was called FACILITIES_REV3; it contains 56 records.
- The Consultation with Facility and HVAC Managers (Part 2) File was called CONSULT2_REV3: it contains 61 records.

2.7.4 Preparation of Classroom-level Analysis Files

The classroom-level Phase II questionnaire data consisted of responses to questionnaire items from the following forms (see Appendix A):

- Teachers Questionnaire
- Classroom Form
- Consultation with Facility and HVAC Managers (Part 1)
- HVAC Assessment Checklist and School Characteristics

These data were stored in separate files and each file was processed separately. As a first step in preparing the data for analysis, a revised version of each file was created. This involved the same basic steps as those indicated above for the school-level files. In addition, the portable/traditional classroom designations from the various files and from the field staff indications (associated with the physical measurements) were reviewed and compared; in the majority of cases the data agreed; where they did not, a consensus portable/traditional indicator (called PT_IND) was created for use in adjusting sample weights and checking consistency of some variables (e.g., items that were only to be answered for portable classrooms).

The final classroom level files included new variables suitable for analysis (see Section 2.9) plus the appropriately adjusted sampling weights (see Section 2.8). Again, cross tabulations of the original and recoded variates were generated and examined. As with the school-level files, we had originally planned to merge the files to form a single classroom-level file. However, since nonresponse patterns differed for the various files, separate sampling weights were needed for each file and thus four separate classroom-level files were retained (1 record per responding classroom):

Source of Data	SAS File Name	No. of Records
Teachers Questionnaire	TEACH_REV3	186
Classroom Form	CLR_REV3	199
Consultation with Facility and HVAC Managers (Part 1)	CONSULT1_REV3	174
HVAC Assessment Checklist and School Characteristics	HVAC_REV3	194

2.7.5 Preparation of Laboratory Data Analysis Files

The following types of laboratory data were received:

- Pollen and spores in air (indoor and outdoor)
- Aldehydes in air (indoor and outdoor)
- Volatile organic compounds (VOCs) in air (indoor and outdoor)
- Bioaerosols (indoor and outdoor) and surface biologicals

– Metals in floor dust
– Pesticides and PAHs in floor dust
– Allergens in dust

Although each type had its own format and its own particular nuances, the basic steps used to process these files were as follows:

1. Conversion of raw data (in various formats) into a SAS file and comparison of acquired samples with anticipated samples.
2. Conversion of raw measurements, coupled with information from the field staff, into appropriate concentration and loading data.
3. Assignment of codes identifying the type of sample/analysis (e.g., a duplicate analysis, a blank sample), the quality of the particular measurement, and the measurability status (detected/ not detected).
4. Extraction of "valid" records from each data file and creation of the following composite files
   - LABDAT – consists of all valid field records
   - DUPSAMP – contains pairs of records for duplicate samples
   - DUPANAL – contains pairs of records for duplicate analyses or duplicate injections
   - FBLKS – contains results of blank sample analyses, by type of blank (e.g., lab blank, field blank)
   - CNTL – contains results (e.g., percent recovery) for various types of control samples.
5. Assignment of appropriate sampling weights and weighting status indicators to LABDAT data records (see Section 2.8).

Steps 1 through 3 were performed for each data type. In cases where data were supplied directly, the processing was minimal. In other cases, extensive processing was required. Step 4 included the following processes:

- Creation of consistently-named variables for the primary measures of interest (e.g., concentrations), for the data quality and measurability status indicators, and for the detection limits
- Averaging over duplicate analyses or duplicate samples (for field data)
- Assignment of media codes to distinguish the media and types of measurements (e.g., indoor air aldehydes, outdoor air aldehydes, dust metals)

The types of available data and the number of data records in the QC files are indicated in Table 2-9.

The types of available data and the number of data records in the final field-data file (called LABDATW) are given in Table 2-10. The LABDATW file maintains a separate data record for each school, location (e.g., classroom or outdoors), medium (e.g., air), analyte class

Table 2-9. Number of Available QC Observations, By Type

Medium Code and Type	Blank Samples*				Control Samples				Duplicate Samples/Analyses**			
	Type	No. Records	No. Analytes	No. Records /Analyte	Type	No. Records	No. Analytes	No. Records /Analyte	Type	No. Records	No. Analytes	No. Records /Analyte
100 Indoor air pollen/spores	FB	270	27	10					DS	972	27	36
101 Outdoor air pollen/spores									DS	54	27	2
200 Indoor air aldehydes	FB LB	432 60	12 12	36 5	LC	132	12	11	DS	816	12	68
201 Outdoor air aldehydes									DS	216	12	18
300 Indoor air VOCs	FB	64	9	7-8					DS	128	9	12-18
400 Indoor air biologicals	FB	9	9	1					DS	10	5	2
401 Outdoor air biologicals									DS	10	5	2
500 Dust pesticide concentration	LRB LMB	138 137	20 20	6-7 6-7	LFM LFB	116 177	20 20	5-6 8-9	DA DI	264 434	20 20	6-16 10-24
501 Dust pesticide loading									DA DI	232 368	20 20	6-14 10-20
600 Dust PAH concentration	LRB LMB	106 105	16 16	1-7 1-7	LFM LFB	111 109	16 16	6-7 5-7	DA DI	242 338	16 16	10-16 10-24
601 Dust PAH loading									DA DI	212 112	16 16	10-14 4-8
700 Dust allergens – 500µm												
800 Dust metals concentration	LB	72	18	4	LFB SRM	71 61	18 16	3-4 2-4	DA DI	288 396	18 18	16 15-24
801 Dust metals loading									DA DI	252 276	18 18	14 13-16
Total		1393				777				5620		

* Indoor and outdoor air not distinguished. ** There are two records per duplicate.

Type codes: FB=field blank, LB=lab blank, LRB=lab reagent blank, LMB=lab matrix blank, LC=laboratory control, LFB=lab fortified blank, LFM=lab fortified matrix, SRM=standard reference material, DS=duplicate sample, DA=duplicate analysis, DI=duplicate injection

Table 2-10. Number of Available Field Data Observations from Laboratory Analyses, By Type

Medium Code and Type	Unit of Record (C=classroom S=school)	No. Records	No. Analytes	No. Records / Analyte	No. Classrooms (Port/Trad/Total)	No. Schools	Weighted Analysis	Non-Detect Reporting Strategy ‡‡
100 Indoor air pollen/spores	C	4995	27	185	126/59/185		Yes	A
200 Indoor air aldehydes	C	2388	12	199	135/64/199		Yes	B
300 Indoor air VOCs**	C	719	9	73-93	65/28/93		Yes	B
400 Indoor air biologicals†	C	181	5	36-37	27/10/37		No	A
402 Surface biologicals*†	C*	164	4	41	26/10/36		No	A
500 Dust pesticide conc††	C	1363	20	30-78	39/38/77		No‡	B
501 Dust pesticide loading††	C	1002	20	26-57	29/28/57		No‡	B
600 Dust PAH conc††	C	1152	16	54-77	39/37/76		No‡	B
601 Dust PAH loading††	C	842	16	40-56	29/27/56		No‡	B
700 Dust allergens – 500μm	C	935	5	187	129/58/187		Yes	C
701 Dust allergens – 150μm***	C	30	5	6	4/2/6		No	C
800 Dust metals concentration††	C	1404	18	78	40/38/78		No‡	B
801 Dust metals loading††	C	1044	18	58	30/28/58		No‡	B
101 Outdoor air pollen/spores	S	1674	27	62		62	Yes	A
201 Outdoor air aldehydes	S	744	12	62		62	Yes	B
301 Outdoor air VOCs**	S	258	9	26-34		34	Yes	B
401 Outdoor air biologicals†	S	50	5	10		10	No	A
TOTAL		18945						

* Multiple sites at some classrooms.
** VOC subsample.
*** Note: Only as a special study prior to analysis of all floor dust samples.
† Specially selected schools only.
†† Subset of portables selected. Samples from portables composited prior to analysis. Corresponding traditionals selected.
‡ Weighted to reflect classrooms in the sample for which data are available.
‡‡ Reporting strategies are defined as follows:

- A Non-detects are reported as zeros. Detection limits (DLs) are not generally available.
- B Negative values are converted to zeros; otherwise data are not censored. DLs vary by sample.
- C Non-detects are set equal to the DL, which is constant across samples.

Note: Numbers of observations for dust loadings differ from those for concentrations because of missing or unreliable data on the areas sampled.

(e.g., aldehydes), and species (e.g., formaldehyde). Other pertinent identifying information (e.g., date of sampling, type of classroom) are also maintained. Thus this file involves multiple records per classroom (or school) that correspond to the various types of measurements. Three digit codes are used to identify chemical classes/media (henceforth called the media code) and the particular species (henceforth called chemical code). The final file is sorted by media code, chemical code, analysis stratum (see Section 2.8), and classroom or school ID in order to facilitate generation of summary statistics.

2.7.6 Processing of Data from Continuous Monitors

Three types of continuous monitors were employed in the Phase II data collection:

– Q-Trak data: CO, CO_2, temperature, and relative humidity
– Particle count data
– HOBO data: HVAC on/off status.

The processing of each is described briefly below.

Q-Trak Data. These data consisted of CO, CO_2, temperature, and relative humidity measurements for air in classrooms and outside of schools. Time resolution for these data were, in general, one minute intervals, although there were some schools/classrooms with 30-minute intervals, and some with 1-second intervals. Those with 1-second resolution were first converted to 1-minute resolution, while those with 30-minute resolution were flagged as unusable. A number of problems with these data were discovered. For instance, all CO data were judged to be suspect and were flagged accordingly. Also, some consecutive CO_2 values were found to be consistently reported as 6000 ppm, which appeared to be an upper threshold of the instrument; data for these schools/classrooms were flagged as unusable. There were also a number of problems with the dates and times of the loggers; although the dates could generally be determined independently, the accuracy of the times was suspect. Hence the accuracy of some summary measures, especially hour-specific summary measures, (see below) may be poor. Since only a few classrooms had reported data before 7:00 am or after 4:00 pm, data used to construct the summary measures were restricted to be within the 7:00 am-4:00 pm range. Subsequently, we carried out the following steps (for the “valid” 1-minute resolution data):

1. Computed the length of monitoring period.
2. Constructed aggregated measures (restricted to cases with monitoring periods of 240 or more minutes):
   - Computed 5-minute averages; retained any average with 3 or more minutes; computed the maximum 5-minute value and (for temperature and humidity) the minimum 5-minute value; saved the maximum and minimum 5-minute values.
   - Computed 1-hour averages; retained any average with 45 or more minutes; computed the maximum 1-hour value and (for temperature and humidity) the minimum 1-hour value; saved the maximum and minimum values, as well as the hourly averages.
   - Computed and saved overall averages.
   - Computed exceedance indicators for various threshold levels, as shown below:

Parameter	Averaging times	Threshold levels for Indoor Data
CO_2 (ppm)	Overall, hourly, max 5-minute	>1000, >2000
Temperature, EC (EF)	Overall, hourly, max 5-minute	<17 (63), <20(68), >23(73), >26(79), >29(84)
Relative Humidity (%)	Overall, hourly, max 5-minute	<30, >50, >60

3. Assigned appropriate identifiers to indicate the level of aggregation and the data quality.
4. Assigned appropriate sampling weights and weighting status indicators (see Section 2.8).

All of the above summary measures were maintained in two final files: ALLHRSI for indoor (classroom) data and ALLHRSO for outdoor data. Each file contained a separate data record for each classroom or each school. Table 2-11 shows the numbers of valid observations.

HOBO Data. The raw HOBO data records for a given classroom HVAC unit consisted of variables identifying the classroom, the instrument, the date, the HVAC status (on or off), and the start time of that status. Typically, sequential records would show an on-off-on-off pattern. From these data, we attempted the following:

1. Computed the length of monitoring period in minutes and determined the number of time intervals (i.e., status changes) overall and within (wholly or partially) the 7am-to-4pm time window.
2. Corrected dates, where necessary, based on field sampling dates.
3. Computed the overall percentage of time that the HVAC was "on" (restricted to cases with monitoring periods of 240 or more minutes, and restricted to the 7am to 4pm time window if the monitoring period extended beyond that window).
4. Computed the percentage of time the HVAC unit was on within a given hour of day (from 7am to 4pm); retained any percentage that was based on 45 minutes or more.

Data with more than 2000 intervals or less than 3 intervals in the time frame of interest were excluded and those with more than 1000 intervals or a suspect date were flagged as suspect data. These data as a whole are not considered very reliable.

Particle Count Data. The raw particle count data (for a given classroom or outdoors) consisted of the following one-minute counts every five minutes:

- number of particles with diameter over 0.5 Fm
- number of particles with diameter over 2.5 Fm
- number of particles with diameter over 5 Fm
- number of particles with diameter over 10 Fm

The counts for intervals of particle sizes were calculated by subtracting the counts of a subset with narrower size range from those of a large size range. The counts for the size intervals then averaged over time to produce the following:

- the average number of particles/minute with diameter 0.5 to 2.5 Fm
- the average number of particles/minute with diameter 2.5 to 5 Fm
- the average number of particles/minute with diameter 5 to 10 Fm
- the average number of particles/minute with diameter over 10 Fm
- the average number of particles/minute with diameter 0.5 to 10 Fm

Table 2-11. Number of Available Observations for Summary Measures from Continuous Monitors, By Type

Medium and Type	Unit of Record	No. Classroom Observations (Port/Trad/Total)	No. School Observations	Weighted Analysis
Indoor air CO_2	C	92/44/136		Yes*
Indoor air temperature	C	102/46/148		Yes*
Indoor air relative humidity	C	102/46/148		Yes*
Indoor particle counts	C	113/56/169		Yes*
HVAC status	C	48/16/64		No‡
Outdoor air CO_2	S		49	Yes*
Outdoor air temperature	S		52	Yes*
Outdoor air relative humidity	S		28	No
Outdoor particle counts	S		50	Yes*

* Only measures associated with the overall monitoring period are to be weighted; measures for individual hours of the day are not to be weighted.
‡ Weighted to reflect classrooms in the sample for which data are available.

These averages were computed over the entire monitoring period (restricted to the 7am-to-4pm time window), as well as for each hour of the day. Records were retained for cases with a relevant monitoring period of 240 or more minutes. Hourly averages were retained for a given hour of the day if there were 7 or more original records within the hour. Adjusted sampling weights were then augmented onto the file containing these summary measures. Cases for which the logger date and the field sampling date were inconsistent were flagged as suspect records. Numbers of observations appear in Table 2-11.

2.8 Statistical Analysis Weights

2.8.1 Initial School-level Weight

Whenever units are selected from a population with known probabilities, unbiased estimates of population totals (e.g., total number of CA public schools with portable classrooms in the 2001-02 school year) are achieved by weighting the survey responses by the reciprocals of their probabilities of selection, including appropriate adjustments for survey nonresponse. Hence, the initial sampling weight for each of the 1,000 CA public schools randomly selected for Phase I of the PCS was the product of 7 and 1.039 (i.e., initial weight = 7.273) to account for selection of a 1-in-7 systematic sample and a random subsample of 1,000 of the 1,039 eligible schools initially selected.

All of the ineligible schools in the Phase I sample (those schools without any portable classrooms in the Spring of 2002) were identified either during data collection or during telephone follow-up of non-responding schools. Hence, the initial weight for each school found to be ineligible for the study because it had no portable classrooms was set to zero. This process resulted in setting the initial weight to zero for 48 of the 1,000 schools in the Phase I sample.

Hence, the PCS sample of 1,000 schools included 952 schools eligible for Phase I of the PCS. Their sampling weight, P1WT4, was the initial weight for schools selected into the Phase II sample.

The Phase II sampling weight for each school in the Phase II sample is the product of this initial weight for all eligible schools in Phase I sample, P1WT4, and the reciprocal of the probability of selection into the Phase II subsample. Because the Phase II sampling design was stratified simple random sampling, the Phase II weighting factor for each school in stratum "h" was

$$P2WT1 = N_h / n_h \ ,$$

where N_h is the number of the 952 eligible schools on the sampling frame in stratum "h," and n_h is the number of sample schools in stratum "h," per Table 2-12. The product of P1WT4 and P2WT1 was the initial sampling weight for each school in the Phase II sample.

However, five of the 86 schools selected for Phase II were found to be ineligible because they had no portable classrooms in use during the 2001-02 school year. The initial weight for these five schools was set to zero, leaving 81 schools with positive initial sampling weights.

2.8.2 Adjustment for School-level Nonresponse

The first stage of nonresponse occurred when 14 eligible sample schools refused to participate in Phase II of the CA PCS, leaving 67 participants. Weighting class methods were used to adjust the statistical analysis weights and reduce the potential for nonresponse bias. Because weighting classes must be based on information known for both responding and nonresponding schools (Oh and Scheuren, 1983), the weighting classes were based on the following information that was known from the sampling frame (the California Public School Directory 2000) for all 81 eligible sample schools:

1. School level (elementary versus not elementary)
2. School location (rural versus not rural)
3. Northern vs. southern California
4. Percent of children receiving AFDC
5. Percent of children receiving Federal meals assistance
6. Expenditure per student.

The 14 Stratum 1 schools that comprised the "Specially Selected Schools" stratum were used as a weighting class for Phase II nonresponse adjustments so that the weight total for this stratum would be preserved. This was possible because of the high response rate that was achieved for this stratum when only one of these 14 schools refused to participate. For the remaining 67 eligible sample schools, we performed a Chi-squared automatic interaction detection (CHAID) analysis (a "tree-growing" algorithm developed by Kass, 1980) to determine the most significant predictors of whether or not the school participated in Phase II. This classification tree algorithm partitioned the eligible sample schools into three clusters that were most predictive of the schools' response status. Those clusters were used as weighting classes. The four weighting classes used for school-level Phase II nonresponse adjustments are defined in Table 2-12.

Table 2-12. Weighting Classes

Weighting Class	Description	Number of Eligible Schools	Percent Responding Schools
1	"Specially Selected Schools" stratum	14	92.86
2	School level = Elementary	38	89.47
3	School level = Not Elementary; 0 = Percent on AFDC ≤ 9.84556	17	52.94
4	School level = Not Elementary; Percent on AFDC > 9.84556 or missing	12	91.67

For each school in weighting class "c" the adjustment for Phase II nonresponse was calculated as follows:

$$Adj(c) = \frac{\sum_{i \in c} w_1(i)\ I_e(i)}{\sum_{i \in c} w_1(i)\ I_r(i)}$$

where the summation is over all schools in weighting class "c," $w_1(i)$ is the initial Phase II sampling weight for the *i*-th school, $I_e(i)$ is a (0,1)-indicator of whether or not the *i*-th school was eligible for Phase II of the CA PCS, and $I_r(i)$ is a (0,1)-indicator of whether or not the *i*-th school participated in Phase II of the CA PCS. When the initial weights are multiplied by these adjustment factors, the sum of the adjusted weights (P2WT5) for the responding schools in each weighting class is identical to the sum of the initial sampling weights (P2WT3) for all eligible schools.

Because the VOC subsample was selected from the Phase II participants, the initial weights for the 35 schools in the VOC subsample (P2WT5S) were constructed from the school-level, nonresponse-adjusted weights, P2WT5. The weights were multiplied by two (2) for each school selected for the VOC subsample and by zero (0) for each school not selected because participating schools were randomly selected for VOC sampling using a 50% sampling rate within each stratum.

Since the nonresponse-adjusted weights, P2WT5, are not identical within each stratum, and because of random sampling at a fixed rate (50%) for the VOC subsample, the weight sums of these VOC subsample weights and the full sample weights were not identical, even though they both estimate the number of schools in the population of eligible schools. Therefore, the VOC subsample weights were calibrated to produce adjusted VOC sample weights (P2WT5V) that reproduce the same estimated population totals as the full Phase II sample. Calibration was performed within the Phase II school-level weighting classes, rather than within sampling strata, to limit the loss of precision due to unequal weighting. The VOC calibration adjustment for all schools in weighting class "c" was

$$VOCADJ(c) = \frac{\sum_{i \in c} P2WT5}{\sum_{i \in c} P2WT5S} \quad .$$

The adjusted weight for all eligible schools in the VOC subsample in weighting class “c” was then

$$P2WT5V = P2WT5S * VOCADJ(c).$$

Some classroom-level data were obtained for all 67 participating schools. Two VOCs were successfully measured in all but one of the 35 schools in the VOC subsample. All other types of school-level data were missing for at least two schools. Hence, weighting class adjustments for nonresponse were implemented for all the other types of school-level data to produce the final school-level analysis weights summarized in Table 2-13.

Table 2-13. Summary of School-level Analysis Weights

Type of Data	Analysis Weight	Number of Participants
Facilities Questionnaire II	P2WT5FAC	56
Consultation with Facilities and HVAC Managers (Part 1)	P2WT5CNSL1	58
Consultation with Facilities and HVAC Managers (Part 2)	P2WT5CNSL2	61
HVAC Assessment Checklist (HVC)	P2WT5HVAC	65
Outdoor air pollen/spores	P2WT5_101	62
Outdoor air aldehydes	P2WT5_201	62
Outdoor air VOCs		
• All other VOCs	P2WT5_301A	28
• Carbon tetrachloride and tetrachloroethylene	P2WT5_301B	34
• Chloroform	P2WT5_301C	28
Outdoor air CO_2	P2WT5SCO2	49
Outdoor air temperature	P2WT5STEMP	52
Outdoor soil metals	P2WT5_901	67
Outdoor particle counts	P2WT5PRTO	50

2.8.3 Initial Classroom-level Weight

In order to compute classroom-level sampling weights, we first constructed a file with one record for each sample classroom, including the backup sample classrooms used in the field. The response status of each sample classroom was then classified as respondent, nonrespondent, or ineligible (i.e., not a classroom or not in use on the day of monitoring). We verified that each participating school had at least three eligible sample classrooms and no more than three participating classrooms, except for one school where only two classrooms were monitored.

Each sample classroom then was classified either as portable or traditional. The classification was based primarily on four data items:

– Classroom Form Item A-5
– HVAC Assessment Checklist Item A-2

– Consultation with Facilities and HVAC Manager (Part 1) Item A-4
– Classification recorded in the chemistry data shell.

When the majority of these sources were in agreement, they were used to classify the room. When there was not a clear majority among these sources, we determined how the classroom was classified when the sample was selected and used that classification.

The classroom-level sampling weight component was then computed by treating the sample of classrooms selected for each of the 67 participating schools as a simple random sample stratified by portable or traditional classroom type. Hence, the classroom-level weight component for every sample classroom was calculated as

$$\begin{aligned} \text{P2WT6} &= N_p / n_p \text{ for portable classrooms} \\ &= N_t / n_t \text{ for traditional classrooms} \end{aligned}$$

where N_p and N_t and the total numbers of portable and traditional classrooms at the school, respectively, and n_p and n_t and the numbers of portable and traditional *sample* classrooms at the school, respectively. The total numbers of portable and traditional classrooms at each school were determined as recorded when the sample classrooms were selected. The numbers in the sample were based on the final sample classroom file, including ineligible sample classrooms (because they were on the sampling frame when the classroom sample was selected).

The initial sampling weight for all eligible sample classrooms was then computed as the product of the school-level weight, the classroom-level weight component, and a (0,1)-indicator of classroom-level eligibility. This resulted in two classroom-level sampling weights, P2WT7 and P2WT7V, for the full sample and the VOC subsample, respectively.

Two of the questionnaires completed at the school level had one column for each of the three sample classrooms: (a) Consultation with Facilities and HVAC Managers (Part 1) and (b) HVAC Assessment Checklist and School Characteristics. An initial classroom-level weight also was computed for each of these questionnaires by using the school-level nonresponse-adjusted weight for each of these questionnaires, which resulted in the initial classroom-level weights, P2WT7CNSL1 and P2WT7HVAC, for these forms, respectively.

2.8.4 Adjustment for Classroom-level Nonresponse

Weighting class weight adjustment procedures were used to adjust for classroom-level nonresponse. The adjustments were calculated using the same weighting classes described in Table 2-12 for school-level nonresponse, except that the adjustments were calculated separately for portable and traditional classrooms, which effectively doubled the number of weighting classes from four to eight.

The Classroom Form and indoor air aldehyde data were obtained for 199 of 201 eligible sample classrooms. Additional nonresponse occurred for all other types of classroom-level data. The final classroom-level analysis weights are summarized in Table 2-14.

Table 2-14. Summary of Classroom-level Analysis Weights

Type of Data	Analysis Weight	Number of Participants
Consultation with Facilities and HVAC Managers (Part 1)	P2WT9CNSL1	174
HVAC Assessment Checklist	P2WT9HVAC	194
Teacher Questionnaire	P2WT9TQ	186
Classroom Form	P2WT9CLR	199
Indoor air pollen/spores	P2WT9_100	185
Indoor air aldehydes	P2WT9_200	199
Indoor air VOCs • All other VOCs • Carbon tetrachloride and tetrachloroethylene • Chloroform	 P2WT9_300A P2WT9_300B P2WT9_300C	 79 93 78
Indoor air CO_2	P2WT9CCO2	136
Indoor air temperature and relative humidity	P2WT9CRH	148
Indoor particle counts	P2WT9CPRTI	169
Dust allergens (# 500µm)	P2WT9_700	187

2.9 Statistical Analysis Methods

2.9.1 Overview of Research Objectives and Data Analysis Strategy

The major part of the data analysis effort involved conducting data analyses and interpreting the results for those analyses directed at the specific research objectives. These research objectives are shown in the first column of Table 2-15. The second column identifies the primary types of analysis variables that were involved – that is, a variable to be subjected to statistical summarization or to be used as a dependent variable in an analysis of variance (ANOVA) or analysis of covariance (ANOCOVA) model. The last column gives the basic statistical approach that was employed.

Objective 1. The first objective (in the first column of Table 2-15) relates to characterizing the quality of the data collection process and the resultant data. Depending on the results of these analyses, some of the subsequent analyses may be judged to be inappropriate. The methods are described in Section 2.9.2. *Results are presented in Section 3.1 and Appendix B*.

Objective 2. The second objective is aimed at characterizing the completeness of the data. Response rates were calculated for the various data types in the manner described in Sections 2.8 and 2.9.3. These response rates were determined overall and for several key subgroups. *Results are presented in Section 3.2.*

Table 2-15. Summary Of Statistical Analyses For Addressing Research Objectives

Research Objective	Data Types	Statistical Analysis Approach
1. To assess data completeness	All	Generate response rates and completion rates.
2. To assess data quality	lab data	Generate summary statistics characterizing concentrations of blank samples, recoveries for control samples, and summary measures of precision for duplicate samples and/or duplicate analyses.
3. To characterize the populations of schools and classrooms (by classroom type (CT)) with respect to selected questionnaire variables	Selected questionnaire items (Tables 2-16 and 2-17)	Generate weighted estimates (and confidence intervals (CIs)) of proportion of schools having given characteristics (see Table 2-16 for list of variables). Generate weighted estimates (and CIs) of proportion of classrooms, overall and by CT, having given characteristic (see Table 2-17 for list of variables).
4. To characterize distributions of pollutants and environmental conditions for C concentrations in outdoor air (over schools) C concentrations in indoor air (over classrooms, by CT) C dust chemical concentrations (over classrooms, by CT) C environmental measures (e.g., light) (over classrooms, by CT)	lab data, summary measures from continuous monitors, continuous measures reported in questionnaires as indicated in Table 2-17	For each CT, use weighted data analyses to produce estimates (and CIs) of distribution parameters such as percent measurable, means, and selected percentiles (10^{th}, 25^{th}, median, 75^{th}, 90^{th} , 95^{th}) for each species. For continuous monitor data, provide estimated means (and CIs) for the various averaging times and estimates (and CIs) of the average proportion of time that threshold levels are exceeded.
5. To characterize performance of HVAC systems.	Continuous and discrete measures of HVAC performance, from HVAC checklist	For continuous performance measures, use weighted data analyses as above to produce estimates of performance distribution parameters., by CT. For discrete measures, estimate proportion of systems with the given characteristic, by CT. Provide confidence interval estimates for all of these estimated parameters.
6. To compare portable and traditional classrooms with respect to pollutants' indoor-air concentrations	Indoor air concentrations for selected species (dependent variable), Outdoor air concentrations for selected species (covariate)	Use analysis of variance (ANOVA) models that test for effects of CT on concentration levels, and analysis of covariance (ANOCOVA) models that test for effects of CT on concentration levels after adjustment for outdoor levels
7. To assess other effects (e.g., classroom age) on pollutants' indoor-air concentrations in each CT	as above, plus selected items from questionnaires	Augment ANOVA and ANOCOVA models to include primary effects such as classroom age (and possible interactions of these with CT, outdoor air levels).
8. To assess effects of HVAC performance and other factors on pollutants' indoor-air concentrations in each CT	as above, plus selected HVAC performance measures	Augment above models to include HVAC performance measures and other factors as covariates (one at a time). Also, for each CT, generate correlations (and/or scatterplots and cross-tabulations) of indoor concentrations with other measures (e.g., age of classroom, HVAC performance)
9. To characterize classrooms in specially selected schools	Biological swab data, formaldehyde and CO_2 data, selected questionnaire items.	Generate unweighted means and medians, by classroom type.

Objective 3. The third objective is concerned with characterizing the populations of schools and classrooms in terms of means or proportions associated with selected questionnaire variables. These variables are listed in Tables 2-16 and 2-17 for school-level and classroom-level variates, respectively. Hundreds of potential variables of interest in the database were screened in order to develop a manageable set for statistical analysis. Selection of variables was based on (one or more of) the following criteria:

Adequacy of sample sizes within categories (typically more than 25 in each category)
Known or suspected effect on IEQ (e.g., an indicator of a pollutant source or ventilation rate)
Anticipated portable-versus-traditional classroom differences.

The particular methods for producing the estimates are described in Section 2.9.4. Special purpose software (SUDAAN (PROC DESCRIPT)) was used to generate estimates of population proportions for the population of schools or classrooms (by classroom type). This software was also used to produce estimates of standard errors or confidence intervals for these estimated proportions (or means) that appropriately reflect the sampling design (e.g., stratification of schools by area, clustering of classrooms within schools. *Results are presented in Sections 3.3, 3.4, and 3.6 and in Appendices C and D.*

Objective 4. Analyses associated with research objective 4, which is one of the primary research objectives, involved use of data from the laboratory file and summary data from the continuous monitors. These analyses were aimed at characterizing distributions for each species of each medium by generating weighted estimates via the SUDAAN (PROC DESCRIPT) software. These estimates include the percent measurable, the mean, and selected percentiles -- for the population of classrooms (overall and by type [portable, traditional]) and for the population of schools (for outdoor measurements). The software also produces estimates of standard errors or confidence intervals for such parameters that appropriately reflect the sampling design. Specific estimation formulae are given in Section 2.9.4. *Results are presented in Sections 3.7 through 3.16 and in Appendices E and F.*

Objective 5. HVAC performance characteristics were summarized using the methods described above for objectives 3 and 4. The variables, in this case, however, involved variables in Table 2-17 related to HVAC performance. *Results are given in Section 3.5 and Appendix D.*

Objectives 6, 7, and 8. The SUDAAN REGRESS procedure (see Section 2.9.4) was employed for the ANOVA and ANOCOVA modeling associated with research objectives 6, 7 and 8. These objectives are concerned with understanding how indoor air quality measures (e.g., pollutant levels, particle counts) are affected by, or associated with, other measures such as those reflecting classroom HVAC performance and outdoor air levels. Analyses associated with these research objectives are meaningful for only those species having a relatively high percent measurable; hence the analyses were restricted to a subset of the species. Models for these variables were built in a sequential fashion, starting with objective 6 and ending with objective 8. Objective 6 models include only classroom type and outdoor concentration level (of the same species as the indoor variable). Models for objective 7 augment this model with another key

Table 2-16. School-Level Analysis Variables

Variable	Description	Level 1	Level 2	Level 3	Level 4	Source*
REGION	Geographic region	North	South			Sample frame
POPSTAT	School location	Urban	Suburb	Rural		Sample frame
SCHTYP	School type	Elem	Middle	High		Sample frame
FACILITIES QUESTIONNAIRE						
NUMPORT	Number of portable classrooms	1-10	11-20	21-30	>30	FQ7a
NUMTRAD	Number of traditional classrooms	1-20	21-40	41-60	>60	FQ7b
NUMTOT	Total number classrooms	1-30	31-60	61-100	>100	FQ7a,b
HVACLOG	HVAC maintenance logs kept	Yes	No	DK		FQ11a-g
FQ15A	Regular HVAC inspection/maintenance	Yes	No	NA		FQ15a
RFQ16B	Freq of vacuuming/sweeping/dusting	5/wk	3-4/wk	Other		FQ16b
USETOL	Awareness/use of EPA IAQ Tools	Aware/yes	Aware/no	Aware/DK	Unaware	FQ19a,b
FQ25	Any major complaints of envir cond. last yr	Yes	No	DK		FQ25
RFQ25AA	Roof leak complaint last yr: Port	None	Some			FQ25,FQ25aa
RFQ25AB	Plumbing leak complaint last yr: Port	None	Some			FQ25,FQ25ab
RFQ25AC	Air/odor complaint last yr: Port	None	Some			FQ25,FQ25ac
RFQ25AD	Mold complaint last yr: Port	None	Some			FQ25,FQ25ad
RFQ25AE	Temperature complaint last yr: Port	None	Some			FQ25,FQ25ae
RFQ25AF	Noise complaint last yr: Port	None	Some			FQ25,FQ25af
RFQ25BA	Roof leak complaint last yr: Trad	None	Some			FQ25,FQ25ba
RFQ25BB	Plumbing leak complaint last yr: Trad	None	Some			FQ25,FQ25bb
RFQ25BC	Air/odor complaint last yr: Trad	None	Some			FQ25,FQ25bc
RFQ25BD	Mold complaint last yr: Trad	None	Some			FQ25,FQ25bd
RFQ25BE	Temperature complaint last yr: Trad	None	Some			FQ25,FQ25be
RFQ25BF	Noise complaint last yr: Trad	None	Some			FQ25,FQ25bf
PORTCP	Port classroom envir complaints	Yes	No	DK		FQ25,aa-af
TRADCP	Trad classroom envir complaints	Yes	No	DK		FQ25,ba-bf
CONSULTANT FORM (PART 2)						
SCHTYPE	School type (Consultant Form, part 2)	Elem	Middle	High	Other/Mix	DC3
DC8_3	Major water leaks past 5 yrs	Yes	No			DC8_3
RDC9	Ballasts/transformer problems	Yes	No	DK		DC9
RDC10	Standing water	Never	Occasly	Frequent	DK	DC10

* "Source" identifies the questionnaire item(s) from which the variable was derived.

Table 2-17. Classroom-Level Analysis Variables

Variable	Description	Level 1	Level 2	Level 3	Level 4	Level 5	Source
ROOMTYPE	Classroom type	Portable	Traditional				PT_IND
OVERALL	All classrooms	All					
POPSTAT	School location	Urban	Suburb	Rural			Sample Frame
REGION	Geographic region	North	South				Sample Frame
SCHTYP	School type	Elem	Middle	High			Sample Frame
TEACHER QUESTIONNAIRE							
PESTUSE	Pesticide use past yr (teacher)	Current	Previous	Never			TQ8
CAIROK	Classroom air okay	Yes	No				TQ2c
LIGHTOK	Classroom light okay	Yes	No				TQ2d
TURNOFF	Turn off heat/AC due to noise	Yes	No				TQ4
BUGPROB	Bug problems in room	Current	Previous	Never			TQ7a
RODPROB	Rodent problems in room	Current	Previous	Never			TQ7b
MUSTODOR	Musty odor at times	Yes	No				TQ5a
WATRLEK	Leak or flood in room	Current	Previous	Never	Unknown		TQ6a
CONSULTANT FORM (PART 1)							
CLAGEX	Classroom age (yrs)	0-3yr	4-5yr	6-10yr	11-15yr	16+yr	CA3,CA1
PORTREPL	Major addition or replacement (3 yrs)	Some	None	NA			CA8
CLASSROOM FORM							
ROOMAREA	Square feet of floor area [&]	Continuous (actual measured values)					AA6L,AA6W
ROOMAREC	Square feet of floor area [&]	$\leq$ 1,000 sf	>1,000 sf				AA6L,AA6W
AA11	Total number of chairs in room	Continuous					AA11
AB3	Ceiling holes or missing panels	Yes	No				AB3
CWATSTAN	Water stains on ceiling	Yes	No				AB5
CEILMOLD	Mold areas on ceiling	Some	None				AB6
CARPET	Carpet/rugs on floor	Yes	No				AC2_02, AC2_07
AC3	Indoor walk-off mat	Yes	No				AC3
FWATSTAN	Water stains on floor	Yes	No				AC7
TAKWALL	Tackboard walls	Yes	No				AD1_01
BORDWALL	Fiberboard, plywood, particle board walls	Yes	No				AD1_02, AD1_07
SHETWALL	Sheetrock or plaster walls	Yes	No				AD1_03
OTHRWALL	Other wall material	Yes	No				AD1_04, AD1_05, AD1_06 AD1_08SP

Variable	Description	Level 1	Level 2	Level 3	Level 4	Level 5	Source
PNTPEN	Paints/pens in room	Yes	No				AE4_01, AE4_02,
AE4_03	Whiteboard markers in room	Yes	No				AE4_03
AE4_04	Chalk in room	Yes	No				AE4_04
FRESHNER	Air freshener	Some	None				AE6_05
PETSPLNT	Animals and plants	Some	None				AE9_07
AE11_03	Bookcase – pressed wood	Yes	No				AE11_03
AE12_03	Cabinet – pressed wood	Yes	No				AE12_03
CABNEW	New bookcases/cabinets	Yes	No				AE14, AE15_02, AE15_03
DESKNEW	New desks/tables/chairs	Yes	No				AE14, AE15_01, AE15_04
PST_CIDE	Pests or pesticides	Some	None				AE16_07
CHEMPROD	Chemical products	Some	None				AE17_11
MOLDAREA	Mold areas	Some	None				AF11
ACTVOUT	New const. &/or repairs affecting IAQ	Yes	No				AG1_01, AG1_02
OTHRACTV	Other campus activities affecting IAQ	Yes	No				AG1_03, AG1_04, AG1_08
AG6	Outdoor walk off mats	Yes	No	DK			AG6
AG8_01	Parking lot/roadway within 50 ft	Yes	No				AG8_01
SKIRTHT	Foundation skirt height (portables only)	≤ 2 in.	2-12 in.	>12 in.	NA		AH6,PT_IND
ROOFTYPE	Type of roof	Tar & gravel	Metal	Other/DK			AH7
ROOFPTCH	Pitch of room	Flat or Both	Sloped				AH8
WALLCOND	Exterior wall condition	Good	Fair or poor				AH11
WALLMOLD	Mold areas on exterior walls	Some	None				AH14
AH16_02	Chipped paint on exterior wall	Yes	No				AH16_02
AI2	Windows open today	Yes	No				AI2
AI6	Door(s) left open today	Yes	No				AI6
VACMTYPE	Vacuum type	Beat brush/ power head	Canister	Other/DK			AI8
RAA9_01	Musty odor at times	Yes	No				AA8,AA9_01
RAA9_02	Air freshener odor at times	Yes	No				AA8,AA9_02
RAA9_05	New carpet/furniture odor at times	Yes	No				AA8,AA9_05
GENINST	General instruction classroom	Yes	No				AA13
HVAC FORM							
HVACMODE	HVAC mode	Heating	Cooling	Fan only	NA		BB2

Variable	Description	Level 1	Level 2	Level 3	Level 4	Level 5	Source
BB4_C	Outdoor air flow (cfm)	Continuous – form averages by HVACMODE categories					BB4_C
OAPERS	Outdoor air flow per person &&	Continuous – form averages by HVACMODE categories					BB4_C, AA11
OASF	Outdoor air flow per square feet &&&	Continuous – form averages by HVACMODE categories					BB4_C, AA6
TOTSAIR	Total supply air flow (cfm)	Continuous – BB4D+BB4E-- form averages by HVACMODE categories					BB4_D, BB4_E
MOISTA	Max wall, ceiling, floor moisture (%)	Max=0	Max>0				BB5a-f,
BB6_C	Mid-room light	Continuous – form averages					BB6_C
RBB7ICY	Noise –indoor center-HVAC on	Continuous – form averages					BB7ARIC, B7B_RIC
RBB7IRY	Noise –near register-HVAC on	Continuous – form averages					BB7ARIR, B7B_RIR
RBB7OY	Noise –outdoor -HVAC on	Continuous – form averages					BB7AROU, B7B_ROU
RBB7ICN	Noise –indoor center-HVAC off	Continuous – form averages					B7C_RIC, B7D_RIC
RBB7IRN	Noise –near register-HVAC off	Continuous – form averages					B7C_RIR, B7D_RIR
RBB7ON	Noise –outdoor -HVAC off	Continuous – form averages					B7C_ROU, B7D_ROU
RBC4	AHU location	Wall	Window	Rooftop	Other/NA		BC4
RBC5	Type heating system	Forced air	Radiant	Heat pump	Other/NA		BC5
RBC6	Heating fuel	Electricity	Nat gas	Other/NA			BC6
HVACAGE	HVAC age	Continuous – form averages (2002-year built)					BC11
AHUAXS	Ease of access to AHU interior	Good	Fair	Poor/None			BG1
FLTRLDG	Dirt loading on filter	Heavy	Medium	Light	DK/NA		BG5
FLTRGAP	Size of gap around filter	≥ ½”	< ½”	None	DK/NA)		BG6
FLTRMOLD	Mold or mildew on filter	Yes	No	DK/NA			BG7
BG11_1	Clean condensate drain pans & lines	Yes	No				BG11_1
STANWATR	Standing water in drain test	Yes	No	NA			BG13_1, BG13_10
BLKDRAIN	Blocked drain in drain test	Yes	No	NA			BG13_2, BG13_10
DRNFAIL	Drain test failure	Yes	No	NA			STANWATR, BLKDRAIN
OABLOCK	Air intake blocked	Yes	No	DK/NA			BG15B

* “Source” identifies the questionnaire item(s) from which the variable was derived.

& Square feet of floor area = Width x Length of room dimensions (from AA6 values).

&& Outdoor air flow per person = outdoor air cfm / number of seats in room (from BB4C and AA11, respectively).

&&& Outdoor air flow per square foot = outdoor air cfm / floor area of room (from BB4C and ROOMAREA [actual measured value, continuous] , respectively).

explanatory variable (e.g., classroom age) to form a base model that serves as the starting point for the objective 8 modeling, which investigates effects of other variates, one at a time. *Results are presented in Section 3.17.* Various candidate independent variables were considered for objectives 7 and 8.

The models were fit using SUDAAN to properly account for sample design features (e.g., clustering of classrooms within schools) in the estimation of variances of the model parameter estimates. Results of these ANOVA and ANOCOVA tests were summarized by providing the p-values associated with the adjusted Wald F tests (see *SUDAAN User's Manual, Release 8.0* (2001)). These tests are analogous to the usual F tests used in classical ANOVAs. Details on the models and the methods are given in Section 2.9.4.

Objective 9. For the biologicals-in-dust data, observations were available from a small, purposefully selected group of classrooms. Various sampling sites were used in the various classrooms, and in some cases, multiple sites occurred in the same classroom. As a result, the original objective – summarizing these data in terms of (unweighted) means – did not appear reasonable. These data were simply listed. Formaldehyde and bioaerosol data were summarized in terms of unweighted means. CO_2 data and selected questionnaire items were also summarized. *Results are given in Section 3.18*.

Tables 2-18, 2-19, and 2-20 indicate the programs used for data processing and analysis and provide an overview of the various steps involved in the effort.

2.9.2 Quality Control Analyses

The Quality Control (QC) data were of four fundamental types:

Blank Samples. These data were summarized by computing the mean (mass or concentration) level and the standard deviation of the levels, by analyte, medium, and type of blank sample.

Control Samples. These data were summarized by computing the mean percent recovery and the standard deviation of the recoveries, by analyte, medium, and type of blank sample.

Duplicate Samples. These data were summarized by computing the standard deviation (SD) and relative standard deviation (RSD) of each duplicate pair and then summarizing the distribution of these SDs and RSDs, by analyte and medium. Statistics reported included the mean, the median, and the maximum of the RSDs.

Duplicate Analyses. These data were summarized by computing the SD and RSD of each duplicate pair and then summarizing the distribution of these SDs and RSDs, by analyte, medium, and type of duplicate (analysis or injection). Statistics reported included the mean, the median, and the maximum of the RSDs.

Results summarizing the QC data are presented in Section 3.1 and Appendix B. Appendix B also summarizes detection limit information.

Table 2-18. Summary of Programs Used to Process and Analyze Questionnaire Data

Program	Input Files	Description	Output Files	Print Files
1. RECODSCH_AG	FACILITIES CONSULT2	Recode selected variables and create school-level analysis variables	FACILITIES_REV2 CONSULT2_REV2	
2. CONSULT1_REV2	CONSULT1	Recode selected variables and create classroom-level analysis variables	CONSULT1_REV2	
3. CLR_REV2	CLASROOM	Recode selected variables and create classroom-level analysis variables	CLR_REV2	
4. HVAC_Rev2	HVAC	Recode selected variables and create classroom-level analysis variables	HVAC_REV2	
5. TEACH_REV2	TEACH	Recode selected variables and create classroom-level analysis variables	TEACH_REV2	
6. CRSLABVR	(user-supplied labels/formats)	Create file of labels and formats for school-level analysis variables	SLABVAR	SCHLABL
7. CRLABVAR	(user-supplied labels/formats)	Create file of labels and formats for classroom-level analysis variables	LABVAR	VARDEFS
8. AUGWTS (Should be run after SCHWGTS and CLRWGTS programs.)	STRATIDS SCHWGTS CLRWGTS FACILITIES_REV2 CONSULT2_REV2 CONSULT1_REV2 HVAC_REV2 CLR_REV2 TEACH_REV2	Generate counts of eligible and responding schools and classrooms, generate response rates, augment sampling weights and analysis strata codes onto questionnaire files	FACILITIES_REV3 CONSULT2_REV3 CONSULT1_REV3 HVAC_REV3 CLR_REV3 TEACH_REV3	RESP_RATQ
9. POPCHAR2	FACILITIES_REV3 CONSULT2_REV3 SLABVAR	Generate population percentages for selected school level variables using SUDAAN PROC DESCRIPT	SCHPCT	POPCHAR2 (Appendix C)
10. POPCHAR1	CONSULT1_REV3 HVAC_REV3 CLR_REV3 TEACH_REV3 LABVAR	Generate population percentages for selected classroom level variables, overall and by classroom type, using SUDAAN PROC CROSSTAB; perform Wald chi-square tests to test for association of room type with selected variables	CLASPCT	POPCHAR1 (Appendix D)
11. WTDQSTAT	HVAC_REV3 CLR_REV3	Generate population estimates, via SUDAAN PROC DESCRIPT, for characterizing continuous measurements, by classroom type, and (for some variables) by HVAC mode Compare portable vs. traditional means.		POPESTQ (Appendix D)

Table 2-19. Summary of Programs Used to Develop and Adjust Sampling Weights

Program	Input Files	Description	Output Files
1. SCHWGTS	Sample Frame Data	Generate adjusted school-level sampling weights for data analysis	SCHWGTS
2. CLRWGTS	Sample Frame Data	Generate adjusted classroom-level sampling weights for data analysis	CLRWGTS
3. GETSTRAT	SCHWGTS	Collapse strata to form analysis strata	STRATIDS

Table 2-20. Summary of Programs Used to Process and Analyze Laboratory and Continuous Monitor Data

Program	Input Files	Description	Output Files*	Print Files
1. CONTINVAR2	CONTINU	Create summary variables from 1-minute Q-Trak data characterizing CO_2, temperature, and relative humidity	ALLHRSI ALLHRSO	
2. HOBODAT	HOBO	Create summary variables from times and HVAC on/off indicators	HOBOSUMRY	
3. PARTICLES	PARTICLES	Create summary variables from 1-minute particle count data (every 5 minutes)	PARTCNTI PARTCNTO	
4. CRLABDAT	AIRVOC ALLSLIDE BIOPART DUSTMETLS MAINAHYDE ALLERGEN SOILDUST DUSTPEST	Create combined file of field data; extract QC data and separate into appropriate QC files. (Note: ALLHRSI, ALLHRSO, HOBOSUMRY, PARTCNTI and PARTCNTO files are also used as input files, but only for the purpose of identifying which schools and classrooms have data of those types.)	LABDAT FBLKS CNTL DUPSAMP DUPANAL MSLIST CLRCHEMIDS SCHCHEMIDS	
5. AUGWTSCHEM (Should be run after SCHWGTS and CLRWGTS programs.)	LABDAT CLRCHEMIDS SCHCHEMIDS SCHWGTS CLRWGTS	Augment sampling weights onto LABDAT file; generate response rate information for LABDAT, ALLHRSI, ALLHRSO, PARTCNTI and PARTCNTO data.	LABDATW	RESP_RAT
6. QCANAL1	FBLKS CNTL DUPSAMP DUPANAL MSLIST	Generate summary statistics characterizing the QC data (blanks, controls, duplicate samples, and duplicate analyses)		QCANAL2 (Appendix B)
7. LABSUMRY	LABDATW MSLIST	Generate school and classroom distributional estimates, via SUDAAN PROC DESCRIPT, for characterizing concentrations, loadings, etc. For classroom data, generate distributional estimates overall and by classroom type and compare population means (portable vs. traditional).	OUTPCTL OUTPCTLC OUTMEAND	LABSTATS (Appendix E)
8. AUGWTS (Should be run after SCHWGTS and CLRWGTS programs.)	ALLHRSI ALLHRSO PARTCNTI PARTCNTO HOBOSUMRY SCHWGTS CLRWGTS	Augment sampling weights onto ALLHRSI, ALLHRSO, PARTCNTI, PARTCNTO, and HOBOSUMRY files (Note: Hourly data in these files and all data in the HOBOSUMRY file are not population-weighted; rather they are weighted only to reflect the numbers of classrooms in those schools for which usable data were actually acquired.)	CONTINIW CONTINOW PARTCNTIW PARTCNTOW HOBOSUMRY	
9. WTTSISTAT	CONTINIW CONTINOW PARTCNTIW PARTCNTOW HOBOSUMRY	Generate school and classroom distributional estimates, via SUDAAN PROC DESCRIPT, for characterizing summary measures. For classroom data, generate distributional estimates overall and by classroom type. Compare portable vs. traditional means.		WTD_TSI (Appendix F)
10. WTEDREGC (WTEDREGS1)	LABDATW CONTINIW PARTCNTIW PARTCNTOW All _REV3 questionnaire files MSLIST SLABVAR LABVAR	Use SUDAAN PROC REGRESS to fit weighted ANOVA and ANOCOVA models for comparing portable vs. traditional classrooms, after adjustment for outdoor levels .(where applicable) and for other selected independent variables (e.g., classroom age)	AMODLRESL BAMODLRESL CMODLRESL CHECKA CHECKB CHECKC (WTEDREGS1) (Appendix H)	REGC1 (Appendix G)

* MSLIST is file providing an index of media and analyte codes and descriptions. CLRCHEMIDS and SCHCHEMIDS are files containing indices that indicate, at the classroom and school level, respectively, whether a particular type of data is available.

2.9.3 Determination of Response Rates

Nonresponse occurs in the CA PCS Phase II study at two levels: schools and classrooms. Therefore, response rates were calculated at both levels. Several different types of data collection forms and environmental samples were collected at each school and for each classroom. Weighted response rates were calculated for each type of data collected. The weighted response rate is an estimate of the response rate that would have been obtained if we had conducted a census instead of a sample survey.

Each weighted response rate is the sum of the initial sampling weights of the respondents divided by the sum of the same initial sampling weights over all eligible schools or classrooms. Table 2-21 describes how each weighted school-level and classroom-level response rate was calculated. The classroom-level response rates calculated as described in Table 2-21 are conditional response rates because they estimate the percentage of responding classrooms within the population of responding schools (i.e., they are conditional on the set of responding schools). The overall unconditional classroom-level response rates also were computed. They are the products of the school-level and conditional classroom-level response rates. The Phase I response rates are not a factor in this calculation because the Phase II sample was selected from all eligible schools in the Phase I sample, rather than the Phase I respondents. *The resulting estimated response rates are presented in Section 3.2.*

2.9.4 Estimation and Hypothesis Testing Methods

Proper analysis of data collected for members of a probability sample requires that all observations be weighted inversely to their probabilities of selection. These sampling weights enable design-unbiased estimation of linear population parameters, such as population totals. As described above, initial sampling weights were developed as a part of the sample design activities, and, after data collection, these sampling weights were adjusted to compensate (at least partially) for the potential bias resulting from survey nonresponse. Weighting class adjustment procedures, for instance, were used in this study to make the adjustments. The remainder of this section indicates how the adjusted sampling weights were employed in making estimates of various population parameters.

Estimates of Summary Statistics. A common example requiring weighted data analysis is estimation of a population proportion. For instance, for estimating a proportion P_x, the general form of the estimate is

$$\hat{P}_x = \Sigma w_i X_i / \Sigma w_i$$

where the summations are over all sample participants, where w_i denotes the sampling weight associated with classroom (or school) i, and where X_i is an indicator variable with a value of 1 if classroom (or school) i has the characteristic of interest and with a value of 0 otherwise. Note that the numerator is an estimate of the total number of classrooms (or schools) in the population having the characteristic, and the denominator is an estimate of the total number of classrooms (or schools) in the population. This type of estimate is used to characterize the population of eligible schools or classrooms (e.g., as in objective 3). For instance, if X is set to 1 for all

Table 2-21. Response Rate Calculations

Response Rate	Numerator	Denominator	Weight
Percent of eligible schools with any data	All 67 sample schools with any data	All 81 eligible sample schools	P2WT3
Percent of eligible schools with Facilities Questionnaire data	All sample schools with Facilities Questionnaire data	All 81 eligible sample schools	P2WT3
Percent of eligible schools with Consultant Part 1 Questionnaire data	All sample schools with Consultant Part 1 Questionnaire data	All 81 eligible sample schools	P2WT3
Percent of eligible schools with Consultant Part 2 Questionnaire data	All sample schools with Consultant Part 2 Questionnaire data	All 81 eligible sample schools	P2WT3
Percent of eligible schools with HVAC Checklist data	All sample schools with HVAC Checklist data	All 81 eligible sample schools	P2WT3
Percent of eligible schools with outdoor air pollen/spores data	All sample schools with outdoor air pollen/spores data	All 81 eligible sample schools	P2WT3
Percent of eligible schools with outdoor air aldehyde data	All sample schools with outdoor air aldehyde data	All 81 eligible sample schools	P2WT3
Percent of eligible schools with outdoor soil metals data	All sample schools with outdoor soil metals data	All 81 eligible sample schools	P2WT3
Percent of eligible schools with outdoor VOC data (product of two factors)	1. All 67 sample schools with any data 2. All schools in the VOC subsample with outdoor VOC data	1. All 81 eligible sample schools 2. All 35 schools in the VOC subsample	1. P2WT3 2. P2WT5V
Percent of eligible schools with outdoor air CO_2 data	All sample schools with outdoor air CO_2 data	All 81 eligible sample schools	P2WT3
Percent of eligible schools with outdoor air temperature data	All sample schools with outdoor air temperature data	All 81 eligible sample schools	P2WT3
Percent of eligible classrooms with Teacher Questionnaire data	All sample classrooms with Teacher Questionnaire data	All 201 eligible sample classrooms	P2WT7
Percent of eligible classrooms with Classroom Form data	All sample classrooms with Classroom Form data	All 201 eligible sample classrooms	P2WT7
Percent of eligible classrooms with indoor air pollen/spores data	All sample classrooms with indoor air pollen/spores data	All 201 eligible sample classrooms	P2WT7
Percent of eligible classrooms with air aldehyde data	All sample classrooms with air aldehyde data	All 201 eligible sample classrooms	P2WT7
Percent of eligible classrooms with dust allergen data	All sample classrooms with dust allergen data	All 201 eligible sample classrooms	P2WT7
Percent of eligible classrooms with indoor air VOC data	All classrooms in the VOC subsample with indoor air VOC data	All eligible classrooms in the VOC subsample	P2WT7V
Percent of eligible classrooms with CO_2 data	All sample classrooms with CO_2 data	All 201 eligible sample classrooms	P2WT7
Percent of eligible classrooms with indoor temperature and relative humidity data	All sample classrooms with indoor temperature and relative humidity data	All 201 eligible sample classrooms	P2WT7
Percent of eligible classrooms with indoor air particles data	All sample classrooms with indoor air particles data	All 201 eligible sample classrooms	P2WT7

classrooms less than 3 years old, and to 0 otherwise, then the result is the proportion of the population estimated to be in that subgroup. Such estimates can also be used to characterize the population distribution of concentration levels over classrooms (e.g., by defining x to be 1 when a classroom has a concentration exceeding a detection limit or some other given threshold level).

If Y_i denotes a measured quantity for classroom i (or school i) (e.g., the concentration of a given chemical), then a similar expression is used to estimate the target population's mean:

$$\overline{Y} = \sum w_i Y_i / \sum w_i$$

The numerator estimates the total of the Y variable that would have been obtained if all members of the target population had been observed, and, as before, the denominator estimates the total size of the target population.

Other research objectives involve estimating classroom concentrations for various domains (subpopulations) of the target population. Such domains are defined in terms of characteristics of the classrooms (or schools)—for example, classrooms in suburban areas. If proportions are to be estimated, then the form of an estimated proportion for a domain d is

$$\hat{P}_x(d) = \sum w_i d_i X_i / \sum w_i d_i$$

where $d_i = 1$ if classroom i is in the domain d and $d_i = 0$ otherwise. Analogously, if means are to be estimated for such domains, then the form of the estimate is

$$\overline{Y}(d) = \sum w_i d_i Y_i / \sum w_i d_i$$

(Note that if the d_i are identically 1, then the domain of interest is the entire target population.)

A large portion of the data analysis for this study is based upon the above four estimation formulae. Estimates for all of the following, for example, can be obtained either directly from one of the formulae or through application of some simple function to the estimates derived from the formulae:

All tabulations and cross-tabulations of questionnaire items (from the same or different forms)
Characteristics of overall distributions of various chemical, biological, or environmental measures

- percent of population with levels > limit of detection (LOD)
- proportion or percent of population with levels > specified guideline levels
- overall arithmetic means
- selected percentiles (10^{th}, 25^{th}, 50^{th} [median], 75^{th}, 90^{th}, 95^{th})

The same types of distributional characteristics for specific domains.

In addition to estimating such population and domain parameters (e.g., proportions, means), it is important to estimate the precision of the estimate, which is usually expressed in terms of its variance or standard error. The estimation of sampling variances and standard errors for statistics calculated from probability sampling data should be based on the randomization distribution induced by the sampling design (i.e., they should account for all features of the sampling design, such as stratification and multistage sampling). Such an approach is robust because it makes no assumptions regarding the distribution of occurrence (e.g., normality) of the survey items. Hence, analyses based on the design-induced distribution provide the most defensible basis for making inferences from the sample to the target population.

The classic approach to estimating standard errors for nonlinear statistics, such as means and proportions, from complex probability sampling designs is a first-order Taylor Series linearization method. Alternative variance estimation techniques for such designs include jackknifing and balanced repeated replication. Standard statistical software packages (e.g., SAS, SPSS, BMDP, IMSL, etc.) do not typically include any of these algorithms for variance estimation. Therefore, special-purpose Survey Data Analysis (SUDAAN) software was used to analyze the survey data (RTI, 2001). SUDAAN estimates standard errors using the classical Taylor Series method because such estimates are both computationally and statistically efficient. The software includes procedures for survey-based estimation of standard errors of population totals, means, proportions, and ratios as well as linear and logistic regression relationships. RTI software for analysis of complex sample survey data has been reviewed by several non-RTI researchers and generally found to be the most efficient such software currently available. For means, proportions, differences in means, or differences in proportions, the precision is generally reported as an approximate 95% confidence interval calculated as the estimate plus or minus two times the standard error of the estimate.

To develop a manageable list of statistical analyses, hundreds of potential variables of interest were screened from the database. Selection of a variable was based on the following criteria:

Sufficient sample size (typically a minimum of 25-50) in two or more categories
A known or suspected effect on indoor environmental quality, such as an indicator of a pollutant source or ventilation rate
In some cases, significant portable/traditional classroom differences.

The method for calculating measures of precision for percentiles is somewhat different. First, the percentile estimate (say, for the p^{th} percentile) is determined by forming a weighted cumulative empirical distribution and determining the point (say, X_p) at which the sum of the weights is 100p% of the total sum of the weights. A domain consisting of all observations with observed values less than X_p is then formed and the proportion of the population falling into this domain (approximately equal to p) is estimated as $\hat{p}$. The standard error of $\hat{p}$ is formed via the Taylor's Series method and a confidence interval for p is formed as $[\hat{p} - t_a s.e.(\hat{p}), \hat{p} + t_a s.e.(\hat{p})]$, where t_α is an appropriate tabulated t value. An inverse interpolation of the empirical cumulative distribution is then used to translate this interval into one for the percentile. That is, the lower confidence limit is that point L_p at which $100(\hat{p} - t_a s.e.(\hat{p}))\%$ of the total sum of the weights occurs, and the upper confidence limit is that point U_p at which $100(\hat{p} + t_a s.e.(\hat{p}))\%$ of the total sum of the weights occurs. This interval, $[L_p, U_p]$, forms an interval estimate for the p^{th} percentile; it is typically asymmetric about X_p. The interval can be translated into a standard error by dividing the interval length (U_p-L_p) by $2t_\alpha$. Although such a standard error statistic cannot be used along with the estimated percentile to directly construct a confidence interval, it can be used to indicate the precision of one estimated percentile relative to another.

All of the above described estimates, standard errors, and confidence intervals can be generated utilizing the SUDAAN procedures DESCRIPT and CROSSTAB.

Analysis of Variance and Covariance Modeling. As noted above, SUDAAN also includes a regression procedure that can be employed to estimate the ANOVA and ANOCOVA models associated with research objectives 6, 7, and 8. As with the means and proportions, the estimated regression coefficients are weighted estimates and their standard errors (and hence tests of hypotheses for the regression coefficients) reflect the survey design features.

For objective 6, the basic models are of the form (error terms are omitted for simplicity):

$Y = a + b_0 R$, or (A1)

$Y = a + b_0 R + c_0 Z$, or (A2)

$Y = a + b_0 R + c_0 Z + c_1 RZ$, (A3)

where the *a*s *b*s and *c*s are parameters to be estimated and where

Y = log(indoor concentration) for a given analyte[3],
R = classroom type indicator = 1 if portable, 0 if traditional,
Z = log(outdoor concentration) for the analyte.

Model (A1) is an ANOVA model, Model (A2) is an ANOCOVA model, and Model (A3) is an extension of the ANOCOVA model that allows different slopes on the Z variable for portable and traditional classrooms (by inclusion of an R by Z interaction term).

For objective 7, the above models (or the one deemed most appropriate) were augmented with another explanatory variable (either a continuous or categorical variable). The models are denoted as (B1), (B2), or (B3), depending on whether they employ (A1), (A2), or (A3) as their base set of terms. For instance, if model (A3) is used as the base model from objective 6, the augmented model would be model (B3) and would have the form:

$Y = a + b_0 R + c_0 Z + c_1 RZ + b_1 X_1$, (B3)

where X_1 is a given independent variable. (This formulation, for purposes of illustration, treats X_1 as continuous or as a discrete variable with only 2 levels [represented as a single dummy variate taking on values of 0 and 1], but if more than two categories are involved, then additional Xs would be included.) Model (B1) would exclude the Z and RZ terms, while Model (B2) would exclude the RZ term.

[3] The log scale is generally preferred for the modeling since variances of measurement errors tend to increase with increasing levels. The log-transform in this situation will tend to produce data with more homogeneous error variances.

For objective 8, a series of additional models for each Y variable were attempted by augmenting the (B1), (B2), or (B3) model with an additional set of dummy variates corresponding to items from selected questionnaire-based categorical variables. These models are denoted as models (C1), (C2), or (C3), depending on the particular B model upon which they are based. The additional variables were treated one at a time, as opposed to attempting to build a overall model that utilizes many variables, for two reasons: (1) sample sizes were not large enough to support the simultaneous inclusion of many such variates, and (2) time and resources for the study were not adequate to allow that type of model development activity to be performed, given that several analytes (i.e., several Y variates) and many candidate predictor variates are of interest. The C type models thus have the following form:

$$Y = a + b_0 R + c_0 Z + c_1 RZ + b_1 X_1 + b_2 X_2 + b_3 X_3 , \qquad \text{(C3)}$$

where (for illustration) X_1 is a continuous variate or dummy variate from model (B3) (equal to 1 if the response is level 1 and to 0 if response is level 2), and where X_2 and X_3 are dummy variates associated with a three-level item (for illustration) – i.e., $X_2 = 1$ if the response is level 1 and 0 otherwise, and $X_3 = 1$ if the response is level 2 and is 0 otherwise. The particular predictors used in the B- and C- models are indicated in the results section (Section 3.16). Additional information on the modeling strategy is given in Section 3.16.1.

Handling of Non-Detects and Low-Level Values. As noted in Table 2-10, three basic strategies were employed in the processing of the laboratory data to deal with non-detectable and negative values. For estimation (summary statistics) and testing, no additional censoring of the measured data was performed. For the ANOVA and ANOCOVA modeling, which was generally performed using log-transformed data (for the Y and Z variables), it was necessary to convert any zero values to a positive value prior to taking logarithms. The positive value used to replace any zero value was set equal to 1/2 of the smallest positive value that was observed among all samples for the particular analyte and medium of interest. Further information on detection limit definitions and values is in Appendix B.

It should be noted that the pesticide and PAH analyses of the dust samples involved use of second-order calibration curves. The lowest point on a calibration curve was adopted as a quantitation limit. All observed values falling below that limit were considered non-detects and were also flagged as “suspect” cases (since they were outside the calibration range). Since cases with zero peak areas are in this category, a number of samples may yield the same “measured” value, which could be either positive or negative (without further censoring). Since blank samples were not (and should not be) subjected to further censorings and since zero peak areas were generally observed, all of the blank samples for these chemicals tend to have the same (possibly negative) value.

3. RESULTS AND DISCUSSION

3.1 Quality Control Results

3.1.1 Field and Laboratory Blanks

Blank samples originate in the field and/or in the laboratory and are processed identically to actual samples. A summary of blank sample results is given in Appendix B. This table gives the following summary statistics of the observed levels (usually in mass units), by medium and analyte and type of blank (e.g., FB = field blank, LB = laboratory blank): the number of blank samples (n), their mean and standard deviation, and the minimum and maximum values.

Appendix B also provides a summary of the values of the detection limits. In general, the blank results were employed in the calculation of the method detection limits. If the analyte(s) of interest were not detected in the blanks, the method detection limit was calculated from the lowest calibration point at which the analyte was detected. Methods of determination of the detection limits for the specific classes of analytes are indicated in Appendix B.

In general, the levels in the blanks were minimal and relatively uniform. Notable exceptions were acetone and acrolein in the air-aldehyde samples and zinc in the dust-metals. Acetone and acrolein results have been excluded from this report. Zinc results were reported without adjustment.

3.1.2 Control Samples

Appendix B also gives the following summary statistics for percent recoveries, by medium, analyte and type of control sample (LFB = lab fortified blank, LC = laboratory control, SRM = standard reference material): the number of control samples; their mean, median, standard deviation, and coefficient of variation (CV); the minimum and maximum recoveries, and the percent of the control samples that were detected. Recoveries of analytes were calculated from control samples (field and/or laboratory) by dividing the amount, or concentration, found by the amount, or concentration, spiked. In most cases, the median recoveries show satisfactory analytical method performance. Zero, and exceedingly small, recoveries are very likely the result of unspiked control samples. Depressed recoveries (e.g., palladium and selenium in dust) are relatively rare and may indicate marginal analytical performance for these species. Exceedingly large recoveries (e.g., acetaldehyde in air; aluminum in dust) are generally the result of the presence of the analyte in the blanks.

Control recoveries, by medium, analyte group and control type are summarized below (n=number of samples):

Medium	Analyte Group	Control Type	n	Median Range (% Recovery)
Air	Aldehydes	Lab Control	11	81.1 - 140.1
Dust	Metals	Laboratory Fortified Blank	3-4	7.3 - 493.3
Dust	Metals	SRM	2-4	19.0 - 101.1
Dust	Pesticides	Laboratory Fortified Blank	8-9	20.3 – 110.7
Dust	Pesticides	Laboratory Fortified Matrix	5-6	9.7 – 112.3
Dust	PAHs	Laboratory Fortified Blank	5-7	71.3 –105.6
Dust	PAHs	Laboratory Fortified Matrix	6-7	37.1 – 99.7

3.1.3 Duplicate Samples

By definition, duplicate samples are "co-located" samples at the point of collection and represent two independent samples of the same environment. Appendix B provides results that characterize the precision of duplicate samples that were obtained at a subset of the schools and classrooms for certain media. For each analyte and each such pair, a standard deviation was first calculated. A pooled standard deviation was then determined. In addition to this statistic, the appendix table reports the number of pairs and the median and maximum standard deviation. It also gives the mean, median, and maximum of the relative standard deviations (RSDs). The median RSD is regarded as the most appropriate measure of precision. Note that whenever one member of a pair has a zero value, then the RSD will be 141.4% (the square root of 2 times 100%). The appendix also presents a summary of duplicate samples for cases where both samples have detectable values. The same statistics as previously are presented, but cases with non-detects are excluded. This reduces the number of pairs in many situations, but there is less distortion of the RSDs.

Median RSDs for results where both values were measurable are summarized below (n=number of pairs):

Medium	Analyte Group	n	Median Range (% RSD)
Indoor Air	Pollen/Spores	1-18	5.6 – 30
Outdoor Air	Pollen/Spores	1	0.2 - 45.4
Indoor Air	Aldehydes	2-33	2.2 - 11.8
Outdoor Air	Aldehydes	2-8	5.0 - 24.2
Indoor Air	VOCs	1-9	7.0 - 22.7

3.1.4 Duplicate Analyses and Duplicate Injections

Duplicate analyses represent separate aliquots of the same sample carried through the entire analytical procedure. Duplicate injections were repeat instrumental analyses of the same sample extract. For certain media and types of analytes, duplicate analyses (DA) or duplicate injections (DI) were used to assess these components of analytical precision. Appendix B characterizes the precision of these types of duplicates, which were obtained for a subset of the field samples. For each analyte and each such pair, a standard deviation was first calculated. A pooled standard deviation was then determined. In addition to this statistic, the table reports the number of pairs and the median and maximum standard deviation. It also gives the mean, median, and maximum of the relative standard deviations (RSDs). The median RSD is regarded as the most appropriate measure of precision. Note that whenever one member of pair has a zero value, then the RSD will be 141.4% (the square root of 2 times 100%). The appendix shows similar results for cases where both analyses produced detectable values. The same statistics as before are presented, but cases with non-detects are excluded. This reduces the number of pairs in many situations, but there is less distortion of the RSDs.

Median RSDs for duplicate analysis and injections where both values were measurable are indicated below:

Duplicate-Analysis RSDs for Floor Dust Samples

Analyte Group	Duplicate Type	Range of Median %RSDs for Concentrations	Range of Median %RSDs for Loadings
Metals	DA	5.9 - 18.6	3.7 - 11.9
	DI	1.8 - 9.7	1.8 - 8.9
Pesticides	DA	1.0 - 22.0	1.0 - 13.4
	DI	0.3 - 8.2	0.2 - 8.2
PAHs	DA	1.5 - 17.5	1.9 - 25.2
	DI	2.0 - 10.5	0.8 - 11.8

The number of pairs upon which the above statistics were based is often quite small (see Appendix B).

3.2 Response Rates

Weighted school-level, classroom-level, and overall study response rates were calculated as described in Section 2.9.3. School-level response rates are reported by type of school (elementary, middle, or high school), school location (urban, suburban, or rural), and geographic region (Northern or Southern California).

Table 3-1 shows that school-level data were successfully collected (both questionnaire data and environmental monitoring data) in 67 of 81 eligible sample schools. Table 3-2 shows that this results in a weighted response rate of 83.0%. However, we also see in this table that the school-level questionnaire response rates ranged from 70.3% for the Facilities Questionnaire to 79.5% for the HVAC checklist. This table also shows that response rates are highest for elementary schools and lowest for high schools. The estimated response rates for rural schools are erratic because there were only five rural schools in the sample. There appears to be little difference in response rates between Northern and Southern California.

Table 3-1. Number of Eligible and Responding Schools for Questionnaire Data

Classification	Category	No. Eligible Schools	Any Data	Facilities Questionnaire	Consultant Part 1 Questionnaire	Consultant Part 2 Questionnaire	HVAC Checklist
Overall		81	67	56	58	61	65
School Type	Elem	47	42	35	37	38	41
	Middle	16	12	11	10	11	12
	High	18	13	10	11	12	12
School Location	Urban	13	12	10	8	10	12
	Suburb	63	50	41	45	46	49
	Rural	5	5	5	5	5	4
Geographic Region	North	36	30	26	26	28	28
	South	45	37	30	32	33	37

Table 3-2. Weighted School-Level Response Rates for Questionnaire Data

Classification	Category	Any Data	Facilities Questionnaire	Consultant Part 1 Questionnaire*	Consultant Part 2 Questionnaire	HVAC Checklist*
Overall		83.0	70.3	71.0	76.0	79.5
School Type	Elem	89.8	76.4	79.3	82.2	86.9
	Middle	76.3	70.8	61.1	70.8	76.3
	High	69.7	51.7	56.7	63.2	60.9
School Location	Urban	92.4	76.6	55.2	74.6	92.4
	Suburb	79.3	66.1	71.8	74.0	77.0
	Rural	100.0	100.0	100.0	100.0	75.4
Geographic Region	North	84.5	70.8	71.7	78.4	76.8
	South	81.7	69.8	70.3	74.0	81.7

* The Consultant Part 1 Questionnaire and the HVAC Checklist were completed for *every* sample classroom (i.e., data were reported for every sample classroom in the responding schools).

Table 3-3 shows the number of schools for which we successfully obtained school-level environmental samples that resulted in usable data. For outdoor air VOCs, the number of schools with usable data varied by analyte. Therefore, Tables 3-3 and 3-4 show results for three sets of VOCs:

a) all other VOCs;
b) carbon tetrachloride and tetrachloroethylene; and
c) chloroform.

We see in Table 3-4 that the response rate for obtaining usable environmental monitoring data ranges from 61.5% for outdoor air CO_2 to 79.8% for some outdoor VOCs.

The 83.0% response rate for school-level participation in Phase II of this study is quite good. This relatively high response rate limits the possibility for nonresponse bias to affect the results. This response rate is much better that the response rate obtained in Phase I of this study (44.7%) for several reasons. The most important reasons are: (1) the field study was based on telephone recruitment, in contrast to the mail survey; (2) we began recruitment early in the school year; (3) we obtained permission from superintendents before contacting principals, and (4) only three staff who had extensive experience recruiting schools were used to make recruitment calls to superintendents and principals (see Section 2.5).

In Table 3-5, we see that conditional classroom-level response rates for the Teacher Questionnaire and the Classroom Form were 93.0% and 98.5%, respectively. When multiplied by the 83.0% school-level response rate, we see that this results in respectable response rate of 77.2% and 81.7% for the Teacher Questionnaire and the Classroom From, respectively.

Table 3-6 shows the numbers of classrooms for which we successfully obtained environmental samples that resulted in usable data. For indoor air VOCs, the number of classrooms with usable data varied by analyte in the same manner as described above regarding outdoor air VOCs. In Table 3-7, we see that conditional classroom-level response rates varied from 70.6% for some indoor-air VOCs to 98.5% for indoor air aldehydes. When multiplied by the 83.0% school-level response rate, we see in Table 3-8 that the resulting overall study-level response rates for classroom monitoring data varied from 58.6% to 81.7%.

3.3 School Characteristics Based on Responses to Questionnaires and Checklists

As discussed in Section 2.4.1, the target population for Phase II of this study consists of all California's K-12 public schools that had at least one portable classroom in both the spring of 2001 and in the 2001-02 school year, including special districts operated by the counties. Hence, traditional classrooms at schools with no portable classrooms are excluded as well as all classrooms at schools in the 2001-02 school year that did not have portable classrooms in the spring of 2001.

The target population for Phase II of the study is estimated to consist of 6,506 schools containing 69,447 portable classrooms and 126,322 traditional classrooms (195,769 total classrooms). These totals are slightly less than the estimated size of the Phase I population because five schools selected for the Phase II sample were found to have no portable classrooms in the 2001-02 school year.

Appendix C characterizes the schools in the target population for selected items from the Facilities Questionnaire and the Consultation Form Part 2. The schools are classified by several school-level variables (e.g., region), and the estimated percentages of the schools falling into each category (e.g., north, south) are shown. The table also gives, for each estimated percentage, the sample size (number of schools) upon which the estimate is based and the approximate 95% confidence intervals for the percentages. Intervals ending in 0 and 100 have been truncated and indicate (a) cases where the coverage probability is actually less than 0.95 and (b) cases where the relative precision is likely to be poor. The estimates are based on weighted data and thus reflect the target population of schools.

Table 3-3. Number of Eligible and Responding Schools for Laboratory and Monitoring Data

Classification	Category	No. Eligible Schools	Any School Data	Outdoor Air Pollen/ Spores	Outdoor Air Aldehydes	Outdoor Air VOCs (a)*	Outdoor Air VOCs (b)*	Outdoor Air VOCs (c)*	Outdoor Air CO2	Outdoor Air Temp	Outdoor Air Particles
Overall		81	67	62	62	28	34	28	49	52	50
School Type	Elem	47	42	38	38	15	20	14	34	34	33
	Middle	16	12	12	11	6	7	7	8	11	9
	High	18	13	12	13	7	7	7	7	7	8
School Location	Urban	13	12	12	11	2	4	2	9	9	9
	Suburb	63	50	46	46	25	28	24	35	38	38
	Rural	5	5	4	5	1	2	2	5	5	3
Geographic Region	North	36	30	25	28	12	15	11	22	23	22
	South	45	37	37	34	16	19	17	27	29	28

* (a) other VOCs, (b) carbon tetrachloride and tetrachloroethylene, (c) chloroform

Table 3-4. Weighted School-Level Response Rates for Laboratory and Monitoring Data

Classification	Category	Any School Data	Outdoor Air Pollen/ Spores	Outdoor Air Aldehydes	Outdoor Air VOCs (a)*	Outdoor Air VOCs (b)*	Outdoor Air VOCs (c)*	Outdoor Air CO2	Outdoor Air Temp	Outdoor Air Particles
Overall		83.0	74.0	77.1	64.6	79.8	63.6	61.5	63.9	62.3
School Type	Elem	89.8	77.6	81.9	62.4	84.0	54.3	68.5	68.5	69.5
	Middle	76.3	76.3	70.8	62.3	76.3	76.3	59.0	70.7	52.9
	High	69.7	60.9	69.7	69.7	69.7	69.7	43.4	43.4	50.6
School Location	Urban	92.4	92.4	84.2	45.0	92.4	45.0	67.0	67.0	67.5
	Suburb	79.3	69.7	73.4	68.0	75.4	62.6	56.6	59.8	60.0
	Rural	100.0	75.4	100.0	50.0	100.0	100.0	100.0	100.0	73.8
Geographic Region	North	84.5	64.7	77.5	62.5	77.5	54.7	63.3	63.6	65.9
	South	81.7	81.7	76.8	66.3	81.7	71.0	59.9	64.2	59.2

* (a) other VOCs, (b) carbon tetrachloride and tetrachloroethylene, (c) chloroform

Table 3-5. Number of Eligible and Responding Classrooms and Weighted Response Rates for Teacher Questionnaire and Classroom Form

Classification	Category	No. Eligible Schools	No. Responding Classrooms Teacher Questionnaire	No. Responding Classrooms Classroom Form	Conditional Response Rate Teacher Questionnaire	Conditional Response Rate Classroom Form	Overall Response Rate Teacher Questionnaire	Overall Response Rate Classroom Form
Overall		81	186	199	93.0	98.5	77.2	81.7
School Type	Elem	47	121	126	95.3	98.3	85.6	88.3
	Middle	16	31	36	88.5	98.9	67.5	75.5
	High	18	34	37	91.2	98.7	63.6	68.8
School Location	Urban	13	33	35	92.8	99.4	85.7	91.8
	Suburb	63	139	149	93.0	98.2	73.7	77.8
	Rural	5	14	15	93.7	100.0	93.7	100.0
Geographic Region	North	36	83	88	93.9	98.3	79.3	83.1
	South	45	103	111	92.5	98.6	75.6	80.6
Classroom Type	Port	N	126	135	89.9	98.1	74.6	81.4
	Trad	N	60	64	94.7	98.7	78.6	81.9

Table 3-6. Number of Eligible and Responding Classrooms for Laboratory and Monitoring Data

Classification	Category	No. Eligible Schools	Indoor Air Pollen/ Spores	Indoor Air Aldehydes	Indoor Dust Allergens	Indoor Air VOCs (a)*	Indoor Air VOCs (b)*	Indoor Air VOCs (c)*	Indoor Air CO2	Indoor Air Temp &RH	Indoor Air Particles
Overall		81	185	199	187	79	93	78	136	148	169
School Type	Elem	47	115	126	122	44	56	44	90	95	110
	Middle	16	36	36	33	19	21	19	25	28	27
	High	18	34	37	32	16	16	15	21	25	32
School Location	Urban	13	35	35	35	7	11	7	25	26	27
	Suburb	63	138	149	138	68	76	67	107	113	129
	Rural	5	12	15	14	4	6	4	4	9	13
Geographic Region	North	36	74	88	84	33	39	30	49	61	76
	South	45	111	111	103	46	54	48	87	87	93
Classroom Type	Port	N	126	135	129	56	65	54	92	102	113
	Trad	N	59	64	58	23	28	24	44	46	56

* (a) other VOCs, (b) carbon tetrachloride and tetrachloroethylene, (c) chloroform

Table 3-7. Weighted Conditional Classroom-Level Response Rates for Laboratory and Monitoring Data

Classification	Category	Indoor Air Pollen/ Spores	Indoor Air Aldehydes	Indoor Dust Allergens	Indoor Air VOCs (a)*	Indoor Air VOCs (b)*	Indoor Air VOCs (c)*	Indoor Air CO2	Indoor Air Temp &RH	Indoor Air Particles
Overall		89.7	98.5	87.9	70.6	88.4	74.9	72.0	74.6	85.8
School Type	Elem	87.6	98.3	96.3	60.8	83.2	64.4	67.8	70.7	86.7
	Middle	98.9	98.9	81.8	78.3	98.3	90.0	71.3	74.3	77.1
	High	84.8	98.7	68.3	93.0	93.0	90.4	86.7	87.7	93.8
School Location	Urban	99.4	99.4	99.4	41.4	100.0	41.4	82.8	84.4	81.7
	Suburb	89.8	98.2	84.2	76.4	85.9	78.4	71.5	73.5	86.4
	Rural	62.1	100.0	99.8	46.6	100.0	78.0	48.3	60.1	89.4
Geographic Region	North	74.4	98.3	96.3	61.1	76.0	59.4	58.7	65.7	88.3
	South	98.6	98.6	83.1	76.7	96.4	84.9	79.8	79.8	84.3
Classroom Type	Port	91.2	98.1	96.2	76.1	93.1	77.5	70.3	75.5	82.6
	Trad	88.8	98.7	83.4	67.3	85.5	73.3	72.9	74.1	87.5

* (a) other VOCs, (b) carbon tetrachloride and tetrachloroethylene, (c) chloroform

Table 3-8. Weighted Overall Classroom-Level Response Rates for Laboratory and Monitoring Data

Classification	Category	Any School Data	Indoor Air Pollen/ Spores	Indoor Air Aldehydes	Indoor Dust Allergens	Indoor Air VOCs (a)*	Indoor Air VOCs (b)*	Indoor Air VOCs (c)*	Indoor Air CO2	Indoor Air Temp &RH	Indoor Air Particles
Overall		83.0	74.4	81.7	73.0	58.6	73.3	62.2	59.8	61.9	71.2
School Type	Elem	89.8	78.7	88.3	86.5	54.6	74.7	57.8	60.9	63.5	77.9
	Middle	76.3	75.5	75.5	62.5	59.7	75.0	68.7	54.4	56.7	58.9
	High	69.7	59.1	68.8	47.6	64.8	64.8	63.0	60.5	61.1	65.4
School Location	Urban	92.4	91.8	91.8	91.8	38.3	92.4	38.3	76.5	78.0	75.5
	Suburb	79.3	71.2	77.8	66.8	60.6	68.1	62.1	56.7	58.3	68.5
	Rural	100.0	62.1	100.0	99.8	46.6	100.0	78.0	48.3	60.1	89.4
Geographic Region	North	84.5	62.9	83.1	81.4	51.7	64.2	50.2	49.7	55.6	74.6
	South	81.7	80.6	80.6	67.9	62.7	78.8	69.4	65.2	65.2	68.9
Classroom Type	Port	83.0	75.7	81.4	79.9	63.1	77.3	64.4	58.4	62.6	68.5
	Trad	83.0	73.7	81.9	69.2	55.8	71.0	60.8	60.5	61.5	72.6

* (a) other VOCs, (b) carbon tetrachloride and tetrachloroethylene, (c) chloroform

Appendix C results include the following characteristics for the target population of schools:

- These schools are about equally split between Northern and Southern California (45.5% in the north and 54.5% in the south).
- These schools are mostly suburban schools (75.8% suburban, 17.1% urban, and 7.2% rural).
- These schools are mostly elementary schools (59.2% elementary, 20.7% middle, and 20.1% high school, based on the highest grade offered).
- Many of these schools (40.1%) have 30 or fewer total classrooms, but 4.4% are estimated to have over 30 portable classrooms.
- Most of these schools (87.9%) report that they perform regular HVAC inspection and maintenance.
- About half (58.7%) report that they keep HVAC maintenance logs, which are required by State regulations.
- Many of these schools (41.7%) are aware of EPA's Tools for Schools program, but few (18.7%) reported that they were using these tools.

These results are consistent with the Phase I findings, except that the awareness and use of the EPA's Tools for Schools program has increased slightly.

Several differences are noted between the proportions of schools that reported environmental problems with, or complaints regarding, environmental conditions in their portable and traditional classrooms in the past year. Table 3-9 shows that higher percentages of schools reported environmental problems and complaints regarding environmental conditions for their portable classrooms. Higher percentages of schools reporting problems or complaints regarding their portable classrooms is consistent with the Phase I findings; however, the percentages of schools reporting problems or complaints is uniformly lower for both portable and traditional classrooms.

Table 3-9. Percentages of Schools Reporting Environmental Problems or Complaints in the Past Year

Problem/Complaint	Portable (%)	Traditional (%)
Roof leak	24.3	12.0
Plumbing leak	4.3	2.6
Air quality/odor complaint	20.2	7.0
Mold complaint	13.4	4.4
Temperature complaint	15.8	17.2
Noise complaint	4.3	0.1
Environmental conditions complaint	32.2	18.9

As noted in the Phase I report, these school-based results must be interpreted with caution because of differences in the numbers of portable and traditional classrooms in the schools and because of differences in the reported frequencies of complaints for the two types of classrooms. It is more appropriate to compare the classrooms using the classroom-level data.

At the classroom level, most types of environmental complaints were reported by at least half of the teachers, in both portable and traditional classrooms (Table 3-10). Moisture-related problems such as leaks and floods were reported in about one-third of the classrooms. Also, a large fraction of teachers in portable classrooms (68%) reported that they turn off the HVAC system due to high noise levels, an activity that had previously been reported anecdotally, and observed in Phase I and in other studies. This behavior was reported significantly less often for traditional classrooms (42%).

Table 3-10. Percentages of Teachers Reporting Environmental Problems or Complaints Currently or Previously

Problem/Complaint	Portable (%)	Traditional (%)
Stuffy air	53.0	50.7
Musty odor	66.6	62.9
Roof leaks, plumbing leaks, or flood	32.1	43.3
Insects	69.5	67.6
Noise from HVAC (turned off HVAC)	68.3	42.2
Lighting	66.9	74.1

3.4 General Classroom Characteristics Based on Responses to Questionnaires and Checklists

Part 1 of Appendix D characterizes the population of eligible classrooms for selected items from the various data collection forms. Some of the general characteristics estimated for this classroom population are as follows:

- About 63.1% of the classrooms are located in Southern California.
- These classrooms are mostly in suburban schools (75.5% suburban, 17.8% urban, and 6.6% rural).
- These classrooms are mostly in elementary schools (59.0% elementary, 22.9% middle, and 18.1% high school, based on the highest grade offered).
- The estimated distribution of the height of the foundation skirt for portable classrooms is as follows: 42.6% are less than 2”, 22.2% are from 2” to 12”, and 35.2% are over 12”.

The first three results are comparable to those observed in Phase I of the study (skirt height data were not collected in Phase I).

General classroom characteristics that were found to be significantly different (at the 5% significance level) between traditional and portable classrooms are summarized in Table 3-11. This table shows that:

- Portable classrooms usually were newer than traditional classrooms (29.1% versus 83.4% over 15 years old).
- Portable classrooms are much more likely to have had a major addition or replacement in the past 3 years (83.6% portable classrooms versus none observed for traditional classrooms).

- Portable classrooms were more likely to have carpet or rugs on the floor (82.0% versus 62.9%).
- Portable classrooms were more likely to have water stains on the floor (13.1% versus 2.0%).
- Portable classrooms were more likely to have tack board, fiber/particle board, or plywood walls, whereas traditional classrooms were more likely to have sheetrock, plaster, or other wall material.
- Portable classrooms were less likely to have chalk in the room (21.6% versus 40.8%).
- Portable classrooms were more likely to have pressed wood bookcases in the room (73.1% versus 49.8%).
- Portable classrooms were more likely to have a metal roof (28.5% versus 2.5%).
- Portable classrooms were used somewhat less frequently for general classroom instruction (87.9% versus 96.5%).

Table 3-11. Estimated Distributions for General Classroom-level Variables That are Significantly Different by Room Type

Classification Variable	p-Value Wald Chi^2	Category	Sample Size	All Classrooms	Portable Classrooms	Traditional Classrooms
Classroom age (yrs)	0.00	0-3yr	16	5.9	10.3	3.3
		4-5yr	26	15.4	28.5	7.7
		6-10yr	16	8.7	19.6	2.3
		11-15yr	21	6.7	12.5	3.3
		16+yr	57	63.4	29.1	83.4
Major addition or replacement (3 yrs)	0.00	Some	32	13.4	83.6	0.0
		None	7	4.3	16.4	1.9
		NA	53	82.4	0.0	98.1
Carpet/rugs on floor	0.02	Yes	155	69.7	82.0	62.9
		No	43	30.3	18.0	37.1
Water stains on floor	0.01	Yes	21	5.9	13.1	2.0
		No	170	94.1	86.9	98.0
Tackboard walls	0.01	Yes	56	23.5	36.5	16.4
		No	143	76.5	63.5	83.6
Fiber/particle board or plywood walls	0.01	Yes	97	41.4	56.9	32.8
		No	102	58.6	43.1	67.2
Sheetrock or plaster walls	0.00	Yes	33	33.1	3.2	49.6
		No	166	66.9	96.8	50.4
Other wall material	0.00	Yes	41	27.1	8.0	37.5
		No	158	72.9	92.0	62.5
Chalk in room	0.04	Yes	53	34.0	21.6	40.8
		No	145	66.0	78.4	59.2
Bookcase -- pressed wood	0.02	Yes	137	58.2	73.1	49.8
		No	61	41.8	26.9	50.2
Type of roof	0.00	Tar&gravel	101	57.2	58.2	56.6
		Metal	32	12.1	28.5	2.5
		Other/DK	54	30.7	13.3	40.8
General instruction classroom	0.05	Yes	177	93.5	87.9	96.5
		No	17	6.5	12.1	3.5

3.5 HVAC Characteristics

Parts 1, 2, and 6 of Appendix D characterize the population of eligible classrooms for selected items from the various data collection forms, including items related to HVAC systems. Items related to the condition and operation of the HVAC systems serving these classrooms are shown in Tables 3-10 and 3-12. The following differences between portable and traditional classrooms were observed to be significant at the 5% level regarding HVAC characteristics:

- Teachers were more likely to turn off the HVAC system due to high noise levels in portable classrooms (68.3% versus 42.2%).
- The HVAC unit was more likely to be wall mounted for portable classrooms (79.8% versus 9.3%).
- The HVAC unit was more likely to be a heat pump for portable classrooms (96.4% versus 76.9%).
- The heating fuel was more likely to be electricity for portable classrooms (98.1% versus 79.3%).
- The air handling unit was more likely to have good access to its interior for portable classrooms (66.1% versus 35.3%).
- The air filter was more likely to have a light loading of dirt for portable classrooms (51.6% versus 42.9%).
- The size of the gap around the filter was more likely to be less than 1/2" for portable classrooms (71.6% versus 46.3%).
- Mildew or mold was more likely to be found on the filter for portable classrooms (1.3% versus none observed for traditional classrooms).
- The HVAC unit was less likely to have clean condensate drain pans and lines for portable classrooms (30.0% versus 56.7%).
- The HVAC unit was more likely to have standing water in the drain test for portable classrooms (55.3% versus 11.1%).
- A blocked drain was more likely to be observed during the drain test for portable classrooms (36.6% versus 6.8%).
- The HVAC unit was more likely to fail the drain test for portable classrooms (58.5% versus 12.4%).
- The air intake for 11 classrooms was blocked, 10 portables and 1 traditional. The estimated population percent with blocked air intake is 5.6% for all classrooms, 10.8% for portable classrooms, and 2.7% for traditional classrooms.

Appendix D also contains distributional statistics (in Parts 2-5 of the appendix) and hypothesis test results (in Part 6) for the following continuous measurements regarding performance of the HVAC systems serving the sample classrooms:

- Outdoor air flow in three different metrics (cubic feet per minute [cfm], cfm per chair, and cfm per square foot of classroom area).
- Total supply air flow (cfm).
- Age of the HVAC unit (years).

Table 3-12. Estimated Distributions for HVAC Classroom-level Variables that are Significantly Different by Room Type

Classification Variable	p-Value Wald Chi^2	Category	Sample Size	All Classrooms	Portable Classrooms	Traditional Classrooms
Turn off heat/AC due to noise (teacher)	0.02	Yes	106	51.6	68.3	42.2
		No	66	48.4	31.7	57.8
Air handling unit location	0.00	Wall	109	35.0	79.8	9.3
		Window	1	0.8	0.0	1.2
		Rooftop	40	37.2	11.9	51.8
		Other/NA	34	27.0	8.3	37.7
Type heating system	0.05	Forced_air	2	1.6	0.0	2.4
		Radiant	6	4.8	1.1	6.8
		Heat_pump	167	83.9	96.4	76.9
		Other/NA	12	9.8	2.5	13.9
Heating fuel	0.01	Electricity	166	85.9	98.1	79.3
		Natural_gas	19	12.1	1.9	17.6
		Other/NA	3	2.0	0.0	3.1
Ease of access to AHU interior	0.00	Good	105	46.9	66.1	35.3
		Fair	48	29.5	27.3	30.9
		Poor/None	32	23.6	6.7	33.8
Dirt loading on filter	0.01	Heavy	22	8.7	8.6	8.7
		Medium	40	22.7	31.6	17.9
		Light	98	45.9	51.6	42.9
		DK/NA	28	22.8	8.2	30.5
Size of gap around filter	0.01	>=1/2in.	22	11.8	14.3	10.5
		<1/2in.	121	55.4	71.6	46.3
		None	25	12.0	10.5	12.8
		DK/NA	21	20.9	3.6	30.4
Mold or mildew on filter	0.01	Yes	1	0.5	1.3	0.0
		No	162	83.5	96.7	76.6
		DK/NA	19	16.0	1.9	23.4
Clean condensate drain pans & lines	0.00	Yes	72	46.6	30.0	56.7
		No	101	53.4	70.0	43.3
Standing water in drain test	0.00	Yes	62	26.9	55.3	11.1
		No	54	29.6	19.3	35.3
		NA	71	43.5	25.3	53.6

Classification Variable	p-Value Wald Chi^2	Category	Sample Size	All Classrooms	Portable Classrooms	Traditional Classrooms
Blocked drain in drain test	0.00	Yes	43	17.5	36.6	6.8
		No	73	39.0	38.1	39.5
		NA	71	43.5	25.3	53.6
Drain test failure	0.00	Yes	68	28.8	58.5	12.4
		No	48	27.7	16.2	34.0
		NA	71	43.5	25.3	53.6

None of these variables were significantly different (at the 5% level) between portable and traditional classrooms. The mean age of the HVAC units serving portable classrooms was 10.1 years, whereas the mean age was 11.3 years for HVAC units serving traditional classrooms. Table 3-13 summarizes the mean air flow measurements, expressed as outdoor air flow and total supply air flow. For all expressions of air flow, it can be seen that the average air flow in the portable classrooms was greater than the air flow measured in the traditional classrooms, but the differences were not statistically significant at the 0.05 level. One difference was significant at the 0.10 level of significance. (See discussion of CO_2 in Section 3.9 below.)

Table 3-13. Summary of Air Flow Measurements

Air Flow Measurement	Type of Classroom	Est. No. of Classrooms	Mean
Outdoor Air Flow (cfm)	All	118,745	808.7
	Portable	56,653	828.2
	Traditional	62,093	790.9
Outdoor Air Flow (cfm/chair)	All	105,107	24.4
	Portable	54,256	25.4
	Traditional	50,852	23.4
Outdoor Air Flow (cfm/sq. ft.)*	All	109,380	0.87
	Portable	53,766	0.95
	Traditional	55,615	0.80
Total Supply Air Flow (cfm)	All	134,747	593.0
	Portable	59,785	636.3
	Traditional	74,962	558.5

*Significant difference (p<0.10) between portable and traditional classrooms.

Part 2 of Appendix D provides estimates of the mean and selected percentiles for these measures separately for all classrooms, portable classrooms, and traditional classrooms. Part 3 of Appendix D provides 95% confidence interval estimates for these same parameters. Part 4 subdivides the estimates further by HVAC mode (heating, cooling, or fan only) but restricts the percentiles for which estimates are provided to the 25th, 50th, and 75th percentiles because of sample size limitations. Part 5 then provides 95% confidence interval estimates of these parameters.

3.6 Indoor Environmental Quality: Light and Noise

The Teacher Questionnaire analysis in Appendix D includes one item regarding whether or not the classroom lighting was satisfactory and one item regarding noise levels. There was no significant difference between portable and traditional classrooms for the teachers' opinions regarding whether or not the classroom lighting was satisfactory. In both cases, most teachers thought the classroom lighting was satisfactory. However, as noted in Section 3.5, teachers in portable classrooms were significantly more likely to turn off the HVAC system due to high noise levels (68.3% versus 42.2%).

Classroom environmental measurements also included light and noise measurements. The light intensity was measured in the middle of the classroom. The mean light intensity was significantly higher for traditional classrooms than for portable classrooms (65.2 versus 55.7 foot-candles). Noise was measured when the HVAC unit was on and again when it was off at two classroom locations: near the center of the classroom and 10 ft from the HVAC return register. In addition, noise was measured outdoors near the HVAC unit both while it was on and while it was off. As shown in Part 6 of Appendix D, none of these six measurements were significantly different (at the 5% significance level) between portable and traditional classrooms. However, the mean noise level was higher at the 0.10 level near the HVAC return register for portables when the HVAC unit was off. Conversely, the mean noise level measured near the center of the classroom was slightly higher in traditional classrooms than in portable classrooms (56.6 versus 56.0). Perhaps this difference reflects the teachers' higher likelihood for turning off the HVAC in portable classrooms (68.3%, versus 42.2% in traditional classrooms).

The Illuminating Engineering Society of North America (IESNA, 2000) suggests light readings greater than 30 foot-candles for viewing materials of high contrast. Measurement results indicate 11 portable classrooms (8.8%) and 3 traditional classrooms (4.4%) did not meet this lighting guideline. IESNA also has a recommendation that greater than 50 foot-candles of light are needed for viewing material of high contrast and small size, or of low contrast and large size. Classroom measurements reveal that 49 Portable classrooms (38.3%) and 17 traditional classrooms (27.2%) did not meet this level of lighting. Thus a higher percentage of the sample portable classrooms failed to meet both recommended levels of classroom lighting than the traditional classrooms.

The American National Standards Institute, Acoustics Society of America (ANSI/ASA, 2002) and the World Health Organization (WHO, 1999) provide classroom acoustics standard guideline values of #35 dBA. All the measured classrooms, both portable and traditional, exceeded this value. Crandell (1992) suggests a value of #45 dBA for unoccupied classrooms. All the portable classrooms exceeded this value, as did 54 traditional classrooms (91.8%). The City of Sacramento and the City of Davis California provide an upper limit standard for nuisance-based outdoor noise of #55 dBA, which is the same value as WHO's Community guidelines for school playgrounds and outdoor areas. Applying this value to the measured indoor noise levels, 61 portable (50%) and 22 traditional (37.5%) classrooms exceeded the guideline value. More portable classrooms failed to meet the recommended guideline value for noise than traditional classrooms.

3.7 Indoor Environmental Quality: Temperature

The Q-Trak monitors provided 1-minute temperature readings for both inside classrooms and outside the sample schools. These data were summarized for each classroom and school in terms of several overall characteristics (e.g., average temperature over the time window of 7am-4pm, or that portion monitored). Hour-specific averages were also determined. All of these measures were then summarized over classrooms or schools. The detailed results are presented in Appendix F, as follows:

Indoor temperature data:

- Weighted estimates of distributional parameters (mean and selected percentiles), for various summary temperature measures – for all classrooms and for portables and traditionals.
- Approximate 95% confidence intervals for these parameters (where appropriate).
- Tests (approximate t tests) of differences in the means of the measures for portable and traditional classrooms.

Outdoor temperature data:

- Weighted estimates of distributional parameters (mean and selected percentiles), for various summary temperature measures.
- Approximate 95% confidence intervals for these parameters (where appropriate).

Tables 3-14 and 3-15 summarize the major temperature results. For each of the selected measures, Table 3-14 gives the estimated number of classroom represented, along with the number of sample classrooms (n), the weighted mean, median, and 95th percentile. Table 3-15 presents similar results for the outdoor data.

Statistically significant differences between portable and traditional classroom were determined for three of the selected measures:

- Portable classrooms had temperatures below 17°C (62.6°F) for more of the time (0.01 level): 6.3% versus 3.2%.
- Portable classrooms had temperatures below 20°C (68°F) for more of the time (0.05 level): 27.0% versus 17.0%.
- The mean of the minimum 5-minute temperatures was 17.1° (62.8°F) for portable classrooms versus 17.9° (64.2°F) for traditionals.

Hourly data summaries are given in Appendix F.

Table 3-14. Summary of Indoor Temperature Data

Variable Description	Room Type	n	Est. No. Classrm	Mean	50th Pctl	95th Pctl
% time TEMP<17 deg C (63°F)**	All	148	195769	4.3	N	28.3
	Port	102	69447	6.3	N	36.0
	Trad	46	126322	3.2	N	16.3
% time TEMP<20 deg C (68°F)*	All	148	195769	20.5	10.7	80.5
	Port	102	69447	27.0	16.8	95.9
	Trad	46	126322	17.0	5.6	69.6
% time TEMP>23 deg C (73°F)	All	148	195769	27.2	15.6	81.7
	Port	102	69447	27.0	19.8	70.4
	Trad	46	126322	27.3	14.6	84.2
% time TEMP>26 deg C (79°F)	All	148	195769	4.4	N	28.5
	Port	102	69447	2.5	N	11.2
	Trad	46	126322	5.4	N	27.7
% time TEMP>29 deg C (84°F)	All	148	195769	2.3	N	9.6
	Port	102	69447	0.8	N	N
	Trad	46	126322	3.1	N	10.2
Avg temperature (deg C)	All	148	195769	21.8	21.9	24.0
	Port	102	69447	21.4	21.5	23.5
	Trad	46	126322	22.0	21.9	24.0
Max 5-min avg TEMP (deg C)	All	148	195769	24.7	24.5	30.8
	Port	102	69447	24.6	24.5	28.6
	Trad	46	126322	24.7	23.9	30.7
Min 5-min avg TEMP (deg C)*	All	148	195769	17.6	18.0	21.1
	Port	102	69447	17.1	17.6	20.7
	Trad	46	126322	17.9	18.0	21.7
Max hourly avg TEMP (deg C)	All	148	195769	23.3	23.1	26.7
	Port	102	69447	23.2	23.2	26.3
	Trad	46	126322	23.3	22.9	26.7
Min hourly avg TEMP (deg C)	All	148	195769	19.8	20.1	22.5
	Port	102	69447	19.2	19.4	22.3
	Trad	46	126322	20.1	20.3	23.0

*Statistically significant difference in means for portables and traditionals (p=0.05).
** Statistically significant difference in means for portables and traditionals (p=0.01).
N=percentile not estimable.

Table 3-15. Summary of Outdoor Temperature Data

Variable Description	n	Est. No. Schools	Mean	50th Pctl	95th Pctl
Avg temperature (deg C)	52	6506	18.2	14.7	30.2
Max 5-min avg TEMP (deg C)	52	6506	22.6	20.5	35.4
Min 5-min avg TEMP (deg C)	52	6506	12.7	12.8	22.5
Max hourly avg TEMP (deg C)	52	6506	21.2	18.3	34.4
Min hourly avg TEMP (deg C)	52	6506	14.6	13.6	26.8

3.8 Indoor Environmental Quality: Relative Humidity

The Q-Trak monitors were used to also capture relative humidity (RH) data. These data were processed similarly to the temperature data. A significant number of outdoor RH data points were not acquired, so that weighted data analyses for those data were not performed. Appendix F contains the detailed results.

Tables 3-16 and 3-17, which are structured similarly to those for temperature, show the indoor and outdoor RH results, respectively. None of the selected measures exhibited statistically significant differences between the means of the two types of classrooms. However, the portables were estimated to have RH levels over 60% more of the time (an average 16.9% versus 12.6% for traditionals). Average RH levels were about 46%.

Table 3-16. Summary of Indoor Relative Humidity Data

Variable Description	Room Type	n	Est. No. Classrms	Mean	50th Pctl	95th Pctl
% time Rel Humidity<30%	All	148	195769	11.3	N	N
	Port	102	69447	11.0	N	N
	Trad	46	126322	11.4	N	N
% time Rel Humidity>50%	All	148	195769	45.3	29.3	N
	Port	102	69447	44.7	39.8	N
	Trad	46	126322	45.6	20.3	N
% time Rel Humidity>60%	All	148	195769	14.1	0.5	69.5
	Port	102	69447	16.9	0.3	91.5
	Trad	46	126322	12.6	0.9	57.5
Avg relative humidity (%)	All	148	195769	46.2	48.6	62.8
	Port	102	69447	46.8	48.6	63.6
	Trad	46	126322	45.9	46.7	61.4
Max 5-min avg rel. humidity	All	148	195769	58.1	59.4	82.1
	Port	102	69447	57.5	58.6	78.1
	Trad	46	126322	58.4	61.4	82.2
Min 5-min avg rel. humidity	All	148	195769	38.9	40.4	55.1
	Port	102	69447	39.4	41.8	56.2
	Trad	46	126322	38.7	40.0	53.7

Variable Description	Room Type	n	Est. No. Classrms	Mean	50th Pctl	95th Pctl
Max hourly avg rel. humidity	All	148	195769	50.3	52.6	69.8
	Port	102	69447	50.8	52.6	69.7
	Trad	46	126322	50.0	50.7	68.6
Min hourly avg rel. humidity	All	148	195769	41.7	43.8	57.7
	Port	102	69447	42.4	44.1	61.3
	Trad	46	126322	41.3	43.0	55.3

Tests of means showed no significant differences between portable and traditional classrooms.
N=percentile not estimable.

Table 3-17. Summary of Outdoor Relative Humidity Data

Variable Description	n	Est. No. Schools	Mean	50th Pctl	95th Pctl
Avg relative humidity (%)	28	28	47.9	48.6	72.3
Max 5-min avg rel. humidity	29	29	68.2	70.5	93.1
Min 5-min avg rel. humidity	29	29	36.8	36.5	64.8
Max hourly avg rel. humidity	29	29	61.7	62.2	88.9
Min hourly avg rel. humidity	29	29	39.5	40.2	68.0

3.9 Indoor Environmental Quality: CO_2 in Air

The real-time CO_2 data were processed in a manner similar to the temperature and RH data and detailed results are provided in Appendix F. Tables 3-18 and 3-19 summarize the overall CO_2 levels indoors and outdoors, respectively. None of the means of the selected measures were judged to be statistically different between the portable and traditional classrooms. Average indoor levels (1070 ppm) were more than twice as high as outdoor levels (427 ppm). The percent of time that CO_2 concentrations exceeded 1000 ppm in California classrooms averaged about 43%. The percent of time that CO_2 concentrations exceeded 2000 ppm was, on average, 9.2 percent for the portable classrooms and 10.1 percent for the traditional classrooms. These results indicate that a number of classrooms often suffer from inadequate ventilation.

3.10 Indoor Environmental Quality: Particle Counts

One-minute particle counts were obtained every five minutes for each of several size fractions. These data were summarized for each classroom (and outdoors) to produce some summary measures, by hour and overall (7am-4pm) as described in Section 2.7. Characteristics of the distributions of these summary measures were then determined for all classrooms and each type of classroom. The details are in Appendix F.

Table 3-18. Summary of Indoor CO_2 Data

Variable Description	Room Type	n	Est. No. Classrms	Mean	50^{th} Pctl	95^{th} Pctl
% time CO2 conc>1000 ppm	All	136	195769	42.8	39.7	95.9
	Port	92	69447	42.1	41.4	86.6
	Trad	44	126322	43.2	39.5	96.0
% time CO2 conc>2000 ppm	All	136	195769	9.8	N	51.4
	Port	92	69447	9.2	N	40.5
	Trad	44	126322	10.1	N	N
Avg CO2 conc (ppm)	All	136	195769	1070.3	959.8	2030.7
	Port	92	69447	1063.5	947.4	1827.3
	Trad	44	126322	1074.1	959.9	N
Max 5-min avg CO2 conc (ppm)	All	136	195769	1770.7	1574.2	3131.1
	Port	92	69447	1898.9	1727.3	3845.4
	Trad	44	126322	1700.3	1542.7	2943.6
Max hourly avg CO2 conc (ppm)	All	136	195769	1489.1	1344.0	2718.5
	Port	92	69447	1555.6	1305.8	2744.1
	Trad	44	126322	1452.5	1333.0	2711.3

Tests of means showed no significant differences between portable and traditional classrooms.
N=percentile not estimable.

Table 3-19. Summary of Outdoor CO_2 Data

Variable Description	n	Est. No. Schools	Mean	50^{th} Pctl	95^{th} Pctl
Avg CO2 conc (ppm)	49	6506	426.5	424.0	510.5
Max 5-min avg CO2 conc (ppm)	49	6506	521.1	504.7	655.3
Max hourly avg CO2 conc (ppm)	49	6506	456.3	459.1	529.5

Table 3-20 summarizes the results in terms of the weighted means, medians, and 95^{th} percentiles of the various measures. None of the means for particle count measures differed significantly between portables and traditionals. There are large differences in estimated 95 percentile values, with the portable classrooms greater than the traditional classrooms, especially for particles of 2.5 µm or less. Table 3-21 shows comparable statistics for the outdoor particle-count data. In both Tables 3-20 and 3-21, observations were considered valid if particle counts were available for at least 240 minutes within the 7 am – 4 pm time window.

Table 3-20. Summary of Indoor Particle Count Data

Variable Description	Room Type	n	Est. No. Classrms	Mean	50th Pctl	95th Pctl
0.5-2.5 um particles/min	All	169	195769	43863	19552	233869
	Port	113	69447	52683	25108	270444
	Trad	56	126322	39015	17616	119291
2.5-5.0 um particles/min	All	169	195769	2157.8	1545.0	6147.2
	Port	113	69447	2072.9	1804.4	4221.8
	Trad	56	126322	2204.4	1461.4	N
5-10 um particles/min	All	169	195769	607.5	444.6	1784.3
	Port	113	69447	589.7	567.2	1162.9
	Trad	56	126322	617.3	424.1	N
>10 um particles/min	All	169	195769	87.8	45.2	318.5
	Port	113	69447	59.4	33.9	250.7
	Trad	56	126322	103.4	55.7	N
<=10 um particles/min	All	169	195769	46629	22988	236032
	Port	113	69447	55345	27203	274934
	Trad	56	126322	41837	20774	121456

Tests of means showed no significant differences between portable and traditional classrooms.
N=percentile not estimable.

Table 3-21. Summary of Outdoor Particle Count Data

Variable Description	n	Est. No. Schools	Mean	50th Pctl	95th Pctl
0.5-2.5 um particles/min	50	6506	79439	37539	364679
2.5-5.0 um particles/min	50	6506	1470.8	948.8	4722.8
5-10 um particles/min	50	6506	182.0	97.2	556.8
>10 um particles/min	50	6506	53.9	26.4	165.0
<=10 um particles/min	50	6506	81092	38482	366973

3.11 Indoor Environmental Quality: Pollens and Spores in Air

Pollens and spores levels in air were determined via analysis of Allergengo slides. These species can be sources of allergic reactions in sensitive people, and some can provide evidence of a potential moisture source or related problem.

Appendix E provides the following detailed results for the pollens and spores data (and the chemical data described in subsequent subsections):

- Part 1: Weighted summary statistics (sample size [n], percentage measurable, mean, and selected percentiles) for outdoor data, by medium and species. The target population is the eligible schools.
- Part 2: Approximate 95% confidence intervals for the percent measurable, mean, and percentiles.

- Part 3: Weighted summary statistics (sample size [n], percentage measurable, mean, selected percentiles) for indoor data, by medium and species. The target population is the eligible classrooms. Statistics are reported for all classrooms and for portables and traditionals.
- Part 4: Approximate 95% confidence intervals for the percent measurable, mean, and percentiles.
- Part 5: Tests (approximate t tests) of differences in weighted means for portable and traditional classrooms, by medium and species.

Table 3-22 summarizes the results for both outdoor and indoor air levels. In general, there were few spore types that were observed frequently in either the outdoor or indoor environments. Specifically, in the outdoor environment, only six were frequently seen. Amerospores, Ascospores, Cladosporium, Mycelial Fragments, Pollen Count, and Total Fungal Spores were observed in at least 80% of the slides. Five of these six (all but Ascospores) were also found at least 80% of the time in the indoor classroom slides. There were no significant differences (at the 5% level) between portable and traditional classrooms.

3.12 Indoor Environmental Quality: Aldehydes in Air

Aldehydes have been shown to result in various health effects, including skin, eye, and respiratory irritants, as well as probable cancer. As indicated above, aldehyde air samples were collected at the (usually) three classrooms and at one outdoor location. Fourteen specific aldehydes were included in the analysis. However, as noted before, acetone was excluded. In the indoor air, valid concentration data were obtained for 199 classrooms. However, only two of the aldehydes were detected in more than 75% of the samples, formaldehyde and acetaldehyde. The mean, median, and 95th percentiles (weighted analysis) are reported in Table 3-23 and more detailed results are included in Appendix E.

Major results from Table 3-23 are:

- For virtually all of the aldehydes, the indoor levels were higher than the outdoor levels, indicating the presence of indoor sources that contribute to the measured levels. Formaldehyde, for example, had a an overall mean level of 13.3 ppb indoors, but only 3.5 ppb outdoors, while the indoor-air 95th percentile was 3 times higher than the outdoor.
- Statistically significant differences (0.05 level of significance) between mean levels of portable and traditional classrooms occur for two analytes:
- Formaldehyde (mean of 15.1 for portables versus 12.3 ppb for traditionals)
- o,p-tolualdehyde, although this analyte has a low percent measurable (~20%).
- Two other comparisons show statistically higher levels in portable classrooms than in traditional classrooms at the 0.10 level of significance: acetaldehyde and 2,5-dimethylbenzaldehyde.

Table 3-22. Summary of Pollen/Spores in Air (log_{10} [Count/m^3])

Analyte	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Alternaria	Outdr	6506	62	71.4	1.15	0.91	2.88
	All	195769	185	65.0	0.79	0.83	1.72
	Port	69447	126	63.3	0.73	0.83	1.57
	Trad	126322	59	65.9	0.83	0.83	1.77
Amerospores	Outdr	6506	62	88.7	1.74	1.85	2.48
	All	195769	185	84.5	1.57	1.76	2.59
	Port	69447	126	84.7	1.59	1.82	2.69
	Trad	126322	59	84.4	1.56	1.72	2.41
Arthrinium	Outdr	6506	62	18.9	0.23		1.44
	All	195769	185	11.4	0.11		0.78
	Port	69447	126	11.1	0.11		0.81
	Trad	126322	59	11.5	0.11		0.65
Ascospores	Outdr	6506	62	82.6	1.59	1.72	3.14
	All	195769	185	71.8	0.92	0.92	1.95
	Port	69447	126	68.1	0.88	0.88	1.84
	Trad	126322	59	73.8	0.93	0.93	1.87
Aspergillus/Penicillium-like	Outdr	6506	62	51.4	1.13	0.87	2.77
	All	195769	185	31.4	0.59		2.37
	Port	69447	126	33.3	0.63		2.37
	Trad	126322	59	30.3	0.57		2.27
Aureobasidium	Outdr	6506	62	0.0	0.00		
	All	195769	185	0.0	0.00		
	Port	69447	126	0.0	0.00		
	Trad	126322	59	0.0	0.00		
Basidiospores	Outdr	6506	62	77.0	1.39	1.61	2.64
	All	195769	185	63.8	0.81	0.84	2.03
	Port	69447	126	72.3	0.86	0.84	2.00
	Trad	126322	59	59.2	0.79	0.74	2.11
Bipolaris/Dreschlera	Outdr	6506	62	47.9	0.63		2.27
	All	195769	185	44.7	0.47		1.69
	Port	69447	126	48.3	0.48		1.33
	Trad	126322	59	42.7	0.46		1.73
Botrytis	Outdr	6506	62	0.2	0.00		
	All	195769	185	0.5	0.00		
	Port	69447	126	1.6	0.01		
	Trad	126322	59	0.0	0.00		

Analyte	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Chaetomium	Outdr	6506	62	15.0	0.14		0.81
	All	195769	185	4.0	0.04		
	Port	69447	126	5.9	0.05		0.82
	Trad	126322	59	3.0	0.03		
Cladosporium	Outdr	6506	62	97.7	2.64	2.60	3.61
	All	195769	185	94.2	1.85	1.91	2.80
	Port	69447	126	89.7	1.76	1.84	2.75
	Trad	126322	59	96.6	1.90	1.93	2.80
Curvularia	Outdr	6506	62	16.7	0.20		1.20
	All	195769	185	19.5	0.21		1.11
	Port	69447	126	19.5	0.17		0.85
	Trad	126322	59	19.5	0.24		1.31
Epicoccum	Outdr	6506	62	0.0	0.00		
	All	195769	185	0.0	0.00		
	Port	69447	126	0.0	0.00		
	Trad	126322	59	0.0	0.00		
Fusarium	Outdr	6506	62	0.0	0.00		
	All	195769	185	0.0	0.00		
	Port	69447	126	0.0	0.00		
	Trad	126322	59	0.0	0.00		
Memnoniella	Outdr	6506	62	0.0	0.00		
	All	195769	185	0.0	0.00		
	Port	69447	126	0.0	0.00		
	Trad	126322	59	0.0	0.00		
Mycelial Fragments	Outdr	6506	62	97.8	1.42	1.26	3.11
	All	195769	185	98.6	1.26	1.24	1.78
	Port	69447	126	99.0	1.22	1.11	1.88
	Trad	126322	59	98.4	1.28	1.24	1.74
Nigrospora	Outdr	6506	62	23.1	0.34		1.81
	All	195769	185	12.2	0.11		0.76
	Port	69447	126	11.0	0.10		0.73
	Trad	126322	59	12.8	0.12		0.77
Oidium/Peronospora	Outdr	6506	62	17.7	0.16		0.88
	All	195769	185	3.7	0.03		
	Port	69447	126	2.0	0.01		
	Trad	126322	59	4.7	0.04		

Analyte	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50^{th} Pctl	95^{th} Pctl
Pithomyces/Ulocladium	Outdr	6506	62	20.2	0.28		1.72
	All	195769	185	22.3	0.21		1.02
	Port	69447	126	25.5	0.22		0.93
	Trad	126322	59	20.6	0.20		1.10
Pollen Count	Outdr	6506	62	97.8	1.32	0.94	2.63
	All	195769	185	98.6	0.92	0.49	1.40
	Port	69447	126	99.0	0.90	0.51	1.28
	Trad	126322	59	98.4	0.94	0.49	1.89
Rusts	Outdr	6506	62	29.8	0.38		1.43
	All	195769	185	31.2	0.31		1.39
	Port	69447	126	31.5	0.31		1.16
	Trad	126322	59	31.1	0.32		1.45
Smuts/Myxomycetes	Outdr	6506	62	62.0	0.96	0.61	2.32
	All	195769	185	64.9	0.83	0.88	1.94
	Port	69447	126	58.1	0.74	0.72	1.87
	Trad	126322	59	68.7	0.88	1.00	1.97
Stachybotrys	Outdr	6506	62	3.2	0.03		
	All	195769	185	1.0	0.01		
	Port	69447	126	0.1	0.00		
	Trad	126322	59	1.5	0.01		
Stemphylium	Outdr	6506	62	3.8	0.07		
	All	195769	185	1.1	0.01		
	Port	69447	126	0.7	0.01		
	Trad	126322	59	1.3	0.01		
Torula	Outdr	6506	62	7.9	0.08		0.40
	All	195769	185	2.6	0.02		
	Port	69447	126	4.2	0.03		
	Trad	126322	59	1.8	0.01		
Total Fungal Spores	Outdr	6506	62	97.8	3.11	3.14	4.21
	All	195769	185	98.6	2.46	2.52	3.31
	Port	69447	126	99.0	2.46	2.45	3.37
	Trad	126322	59	98.4	2.46	2.56	3.29
Unidentified Conidia	Outdr	6506	62	21.7	0.23		1.15
	All	195769	185	12.1	0.11		0.83
	Port	69447	126	5.2	0.05		0.11
	Trad	126322	59	15.8	0.14		0.84

Note: From Allergenco Slides
Note: Blank cells indicate cases where the percentile could not be estimated.

Table 3-23. Summary of Aldehyde Concentrations in Air (ppb)

Analyte	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Formaldehyde*	Outdr	6506	62	100.0	3.48	2.45	8.05
	All	195769	199	100.0	13.29	12.01	23.93
	Port	69447	135	100.0	15.07	14.49	25.78
	Trad	126322	64	100.0	12.31	11.62	22.35
Acetaldehyde	Outdr	6506	62	78.8	5.39	4.36	10.05
	All	195769	199	98.6	6.59	6.17	11.13
	Port	69447	135	100.0	7.02	6.22	12.31
	Trad	126322	64	97.8	6.35	6.09	10.40
Propionaldehyde	Outdr	6506	62	23.4	0.08		0.46
	All	195769	199	54.8	0.27	0.21	0.78
	Port	69447	135	47.0	0.23		0.67
	Trad	126322	64	59.1	0.29	0.22	1.20
Crotonaldehyde	Outdr	6506	62	18.9	0.26		0.99
	All	195769	199	19.5	0.28	0.15	0.94
	Port	69447	135	20.4	0.29	0.18	1.02
	Trad	126322	64	19.0	0.28	0.15	0.85
n-Butyraldehyde	Outdr	6506	62	7.8	0.02		0.05
	All	195769	199	38.9	0.15		0.57
	Port	69447	135	37.6	0.16		0.63
	Trad	126322	64	39.7	0.14		0.57
Benzaldehyde	Outdr	6506	62	21.5	0.09		0.55
	All	195769	199	45.3	0.30		0.97
	Port	69447	135	49.8	0.38	0.17	1.19
	Trad	126322	64	42.9	0.27		0.85
iso-Valeraldehyde	Outdr	6506	62	12.5	0.07		0.48
	All	195769	199	9.8	0.07		0.63
	Port	69447	135	7.6	0.05		0.56
	Trad	126322	64	11.0	0.07		0.62
Valeraldehyde	Outdr	6506	62	10.1	0.01		0.14
	All	195769	199	32.7	0.11		0.39
	Port	69447	135	35.2	0.13		0.51
	Trad	126322	64	31.4	0.10		0.37
Hexanaldehyde	Outdr	6506	62	30.4	0.15		0.82
	All	195769	199	72.9	0.78	0.76	1.86
	Port	69447	135	72.6	0.80	0.67	1.91

Analyte	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
	Trad	126322	64	73.0	0.77	0.77	1.82
2,5-Dimethylbenzaldehyde	Outdr	6506	62	3.9	0.00		0.02
	All	195769	199	1.5	0.00		
	Port	69447	135	2.6	0.01		
	Trad	126322	64	1.0	0.00		
o,p-tolualdehyde*	Outdr	6506	62	1.7	0.00		
	All	195769	199	19.7	0.46		3.98
	Port	69447	135	24.6	0.91		5.27
	Trad	126322	64	17.0	0.21		0.73
m-Tolualdehyde	Outdr	6506	62	0.0	0.00		
	All	195769	199	13.9	0.50		5.10
	Port	69447	135	18.4	0.38		1.99
	Trad	126322	64	11.5	0.57		5.02

*Portables and traditionals significantly different (p=0.05)
Note: Blank cells indicate cases where the percentile could not be estimated.

The indoor formaldehyde levels were also compared to the draft 8-hour indoor reference exposure level for formaldehyde, 27 ppb (Broadwin, 2000). The percentages of classrooms exceeding 27 ppb were estimated as follows (bracketed values are approximate 95% confidence intervals):

Classroom Type	% > 27 ppb	
All	3.3	[0.0, 6.6]
Portable	4.4	[0.4, 8.4]
Traditional	2.7	[0.0, 6.4]

The distributions of formaldehyde measurements from Phase I and Phase II of this study are compared in Table 3-23. As discussed in Section 2.3.2, it is important to remember the many differences in the data collection methods and protocols when interpreting these data. The Phase I measurements were obtained using PF-1 passive monitoring tubes, which were hung in the sample classrooms for 7 to 10 days, including nights and weekends when the schools were closed and HVAC systems may have been off. In contrast, the Phase II measurements were obtained using an active monitoring device during the 6 to 8 hours when classes were in session and HVAC systems were operating normally. Moreover, the Phase I measurements were obtained in the spring and early summer, whereas the Phase II measurements were obtained in the fall and winter. Given these differences (colder weather and better air exchange during the monitoring period), it is not surprising that the Phase II formaldehyde concentrations are considerably lower than those observed in Phase I, especially at the 95th percentile level.

Table 3-24. Comparison of Phase I and Phase II Formaldehyde Distributions

	Sample size (n)		Mean (ppb)		Median (ppb)		95th Percentile (ppb)	
Location	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
Outdoor	NA	62	NA	3.48	NA	2.45	NA	8.05
All classrooms	911	199	27.0	13.29	22.0	12.01	61.7	23.93
Portable	644	135	32.4	15.07	27.1	14.49	71.5	25.78
Traditional	267	64	23.7	12.31	20.0	11.62	55.0	22.35

3.13 Indoor Environmental Quality: VOCs in Air

Similar to the aldehydes, several VOCs have been shown to result in various health effects, including skin, eye, and respiratory irritants, as well as probable cancer. VOC samples were collected in only about half of the sampled schools (usually inside three classrooms and at one outdoor location). Concentrations for nine specific VOC were obtained for the samples collected. Valid concentration data were obtained for varying numbers of classrooms, depending on the particular analyte (73 to 93 classrooms, and 26 to 34 outdoor sites). Seven of the nine had at least 80% of the measured levels above the detection limit. Only benzene and chloroform had less than 80% detectable. The means, medians, and 95th percentiles are shown in Table 3-25 for all the nine measured VOCs. (Detailed results are given in Appendix E.)

Unlike the aldehydes, there was a general tendency for the traditional classrooms to exhibit higher VOC concentrations than the portables. However, none of the differences in mean concentrations were significant statistically, even at a significance level of 0.10. As in most indoor air quality studies, the measured indoor VOC concentrations were higher than those observed outdoors.

3.14 Indoor Environmental Quality: Metals in Floor Dust

Exposure to metals has been shown to be associated with asthma, as well as neurological and developmental effects. For the PCS, metals analyses were obtained from samples collected from floor dust in the classrooms sampled. As noted in Section 2, chemical analysis of dust was done for only a subset of classrooms and dust from the portable classrooms in a given school were composited prior to chemical analysis. Hence population-based weighting (and thus inferences) was not possible and formal testing of differences by classroom type are not considered valid. The data were, however, weighted to reflect the varying numbers of classrooms from school to school and by type of classroom (i.e., inferences are restricted to all classrooms in those schools for which data were obtained).

Tables 3-26 and 3-27 provide a summary of the metal concentration data and the metal loading data, respectively, for the classroom floor dust. Fifteen of the 18 elements were above the detection limit for all of the samples analyzed. The only three metals that were not always above the detection limit were selenium (54%), cobalt (64%), and palladium (34%). For the elements always above the detection limit, the median portable-classroom *concentration* was greater than the median traditional-classroom concentration for 8 of the 15 elements (arsenic, chromium, copper, manganese, vanadium, cesium, iron and strontium. Conversely, the traditionals' medians were higher than the portables' medians for 7 elements (cadmium, lead, nickel, zinc, aluminum, magnesium, and titanium).

Table 3-25. Summary of VOC Concentrations in Air (: g/m^3)

Analyte	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
1,1,1-Trichloroethane	Outdr	6506	28	100.0	1.04	0.88	2.80
	All	194792	78	100.0	1.05	0.65	2.80
	Port	73112	55	100.0	0.79	0.71	1.47
	Trad	121680	23	100.0	1.21	0.61	
Benzene	Outdr	5712	26	32.9	1.04	0.54	2.97
	All	179743	73	63.7	1.75	1.13	4.13
	Port	67612	51	66.6	1.26	0.93	3.00
	Trad	112131	22	62.0	2.05	1.17	4.62
Carbon tetrachloride	Outdr	6019	32	100.0	1.79	1.67	3.64
	All	179633	87	100.0	1.76	0.86	6.07
	Port	66836	61	100.0	1.35	1.18	2.64
	Trad	112797	26	100.0	2.00	0.76	7.99
Chloroform	Outdr	6506	28	41.9	0.45	0.27	
	All	195769	78	75.8	0.41	0.29	1.07
	Port	74089	54	81.7	0.30	0.25	0.44
	Trad	121680	24	72.2	0.48	0.28	
Ethylbenzene	Outdr	6506	28	100.0	0.79	0.73	1.44
	All	195769	79	100.0	1.85	1.17	2.25
	Port	74089	56	100.0	1.44	0.99	2.23
	Trad	121680	23	100.0	2.10	1.26	2.24
Tetrachloroethylene	Outdr	6506	34	100.0	1.08	0.54	3.59
	All	195769	93	100.0	1.40	1.13	3.16
	Port	74089	65	100.0	1.20	1.08	2.43
	Trad	121680	28	100.0	1.53	1.15	3.16
Toluene	Outdr	5712	26	40.3	2.47	2.11	5.45
	All	180175	73	89.7	6.32	5.62	12.25
	Port	68044	51	93.7	6.12	5.32	13.92
	Trad	112131	22	87.3	6.44	6.27	10.31
m,p-Xylene	Outdr	6506	28	100.0	1.99	2.09	3.66
	All	195769	79	100.0	5.17	3.09	7.07
	Port	74089	56	100.0	3.43	2.80	7.16
	Trad	121680	23	100.0	6.24	3.51	6.99
o-Xylene	Outdr	6506	28	100.0	0.86	0.81	1.65
	All	195769	79	100.0	1.94	1.32	2.87
	Port	74089	56	100.0	1.38	1.15	2.57
	Trad	121680	23	100.0	2.27	1.47	2.84

Note: Blank cells indicate cases where the percentile could not be estimated.

Table 3-26. Summary of Metal Concentrations in Floor Dust (µg/g)

Analyte	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50^{th} Pctl	95^{th} Pctl
Arsenic	All	1152	78	100.0	11.57	11.60	17.27
	Port	412	40	100.0	12.74	12.77	18.61
	Trad	740	38	100.0	10.91	11.01	15.33
Cadmium	All	1152	78	100.0	5.00	3.55	13.33
	Port	412	40	100.0	4.81	3.21	8.13
	Trad	740	38	100.0	5.11	3.93	13.38
Chromium	All	1152	78	100.0	36.58	33.10	72.79
	Port	412	40	100.0	35.78	34.44	54.06
	Trad	740	38	100.0	37.02	30.89	73.96
Copper	All	1152	78	100.0	148.81	60.22	287.73
	Port	412	40	100.0	95.11	73.15	193.91
	Trad	740	38	100.0	178.70	57.38	209.41
Lead	All	1152	78	100.0	85.43	61.61	189.51
	Port	412	40	100.0	67.41	57.45	151.64
	Trad	740	38	100.0	95.45	66.76	200.62
Manganese	All	1152	78	100.0	306.47	316.40	416.76
	Port	412	40	100.0	314.48	320.90	395.26
	Trad	740	38	100.0	302.02	301.01	
Nickel	All	1152	78	100.0	41.27	32.24	83.18
	Port	412	40	100.0	36.88	32.00	63.14
	Trad	740	38	100.0	43.71	32.92	85.82
Selenium	All	1152	78	54.1	5.10	1.56	13.50
	Port	412	40	49.5	4.27	0.56	13.28
	Trad	740	38	56.6	5.55	1.82	13.59
Vanadium	All	1152	78	100.0	43.10	39.97	65.04
	Port	412	40	100.0	44.26	42.75	63.39
	Trad	740	38	100.0	42.46	37.87	65.46
Zinc	All	1152	78	100.0	1203.8	980.40	2019.3
	Port	412	40	100.0	1044.7	937.83	1925.4
	Trad	740	38	100.0	1292.3	1026.5	2126.9
Aluminum*	All	1152	78	100.0	47396	47500	60115
	Port	412	40	100.0	44576	43708	59029
	Trad	740	38	100.0	48966	47970	60719

Analyte	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Cobalt	All	1152	78	64.3	6.18	1.70	13.98
	Port	412	40	71.8	4.69	1.67	14.25
	Trad	740	38	60.1	7.01	1.77	12.83
Cesium	All	1152	78	100.0	2.01	1.85	3.24
	Port	412	40	100.0	2.01	1.93	2.99
	Trad	740	38	100.0	2.01	1.77	
Iron	All	1152	78	100.0	23592	22300	37333
	Port	412	40	100.0	23402	23642	30789
	Trad	740	38	100.0	23698	21723	35203
Magnesium	All	1152	78	100.0	9333.7	8700.6	14282
	Port	412	40	100.0	8733.0	8288.1	13401
	Trad	740	38	100.0	9668.1	8793.7	14643
Palladium	All	1152	78	34.5	5.83		19.01
	Port	412	40	26.5	4.61		18.77
	Trad	740	38	38.9	6.52		18.53
Strontium	All	1152	78	100.0	155.50	139.43	234.58
	Port	412	40	100.0	156.95	138.20	257.36
	Trad	740	38	100.0	154.70	144.79	233.58
Titanium*	All	1152	78	99.6	2404.6	2270.9	3675.0
	Port	412	40	98.8	2183.7	2181.5	3007.2
	Trad	740	38	100.0	2527.5	2320.1	

Note: Blank cells indicate cases where the percentile could not be estimated.
*Portable and traditional classrooms are significantly different (p#0.05).

Table 3-27. Summary of Metal Loadings in Floor Dust (ng/cm^2)

Analyte	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Arsenic*	All	860	58	100.0	1.85	1.30	5.53
	Port	313	30	100.0	2.31	1.59	5.52
	Trad	547	28	100.0	1.58	1.14	3.40
Cadmium	All	860	58	100.0	0.70	0.39	2.51
	Port	313	30	100.0	0.74	0.40	2.40
	Trad	547	28	100.0	0.68	0.36	1.70
Chromium	All	860	58	100.0	5.86	3.41	17.83
	Port	313	30	100.0	7.21	3.92	23.89
	Trad	547	28	100.0	5.08	3.16	12.62
Copper	All	860	58	100.0	24.80	6.99	133.38
	Port	313	30	100.0	22.69	7.01	
	Trad	547	28	100.0	26.01	6.99	82.68
Lead	All	860	58	100.0	14.74	6.54	58.39
	Port	313	30	100.0	14.83	5.80	57.88
	Trad	547	28	100.0	14.69	7.14	57.53
Manganese	All	860	58	100.0	48.46	37.80	137.87
	Port	313	30	100.0	59.73	46.91	162.80
	Trad	547	28	100.0	42.02	34.14	92.74
Nickel	All	860	58	100.0	6.74	3.40	24.31
	Port	313	30	100.0	8.07	3.93	38.43
	Trad	547	28	100.0	5.98	3.32	17.70
Selenium	All	860	58	50.3	0.84	0.08	2.59
	Port	313	30	55.3	0.97	0.10	
	Trad	547	28	47.5	0.77	0.04	2.25
Vanadium	All	860	58	100.0	7.00	4.64	17.49
	Port	313	30	100.0	8.47	6.53	20.10
	Trad	547	28	100.0	6.17	4.01	13.73
Zinc	All	860	58	100.0	201.92	107.50	821.72
	Port	313	30	100.0	225.93	108.95	666.85
	Trad	547	28	100.0	188.18	102.77	812.82
Aluminum	All	860	58	100.0	7176.2	5673.0	19157
	Port	313	30	100.0	7543.5	6610.0	18554
	Trad	547	28	100.0	6966.1	5375.3	15659

Analyte	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Cobalt	All	860	58	59.0	1.00	0.10	4.34
	Port	313	30	76.7	1.04	0.11	
	Trad	547	28	48.8	0.97		3.94
Cesium	All	860	58	100.0	0.29	0.24	0.70
	Port	313	30	100.0	0.34	0.26	0.90
	Trad	547	28	100.0	0.27	0.22	0.54
Iron	All	860	58	100.0	3548.2	2858.0	10345
	Port	313	30	100.0	4070.3	3557.9	9993.3
	Trad	547	28	100.0	3249.5	2414.1	7021.4
Magnesium	All	860	58	100.0	1351.2	985.30	4261.5
	Port	313	30	100.0	1484.3	1259.1	4483.8
	Trad	547	28	100.0	1275.1	920.66	2910.6
Palladium	All	860	58	33.1	0.94		4.03
	Port	313	30	28.1	1.05		
	Trad	547	28	36.0	0.88		3.24
Strontium	All	860	58	100.0	25.35	19.57	82.21
	Port	313	30	100.0	30.57	19.95	
	Trad	547	28	100.0	22.35	15.43	54.16
Titanium	All	860	58	100.0	348.18	319.96	877.46
	Port	313	30	100.0	371.28	316.06	914.24
	Trad	547	28	100.0	334.96	253.82	786.76

Note: Blank cells indicate cases where the percentile could not be estimated.
*Portable and traditional classrooms are significantly different (p#0.05).

When the floor dust metals results are reported in terms of a dust loading (see Table 3-27), which adjusts for the area sampled, all of the elements show higher results in the portable classrooms than in traditional classrooms, except for copper. Only the arsenic difference was statistically significant.

3.15 Indoor Environmental Quality: Animal and Arthropod Allergens

Weighted distributional statistics characterizing the allergen levels from sieved dust samples (dust particles less than 500 Fm) that were collected in the sample classrooms are summarized in Appendix E and in Table 3-27. Dog and cat allergens (Canis f1 and Felis d1) were detected in 56% and 74% of the samples, respectively, while the dust mite and cockroach allergens were detected less than 10% of the time. The traditional classrooms had higher estimated mean concentrations for each type of allergen than the portables, but the differences were not statistically significant.

Table 3-28. Summary of Animal and Arthropod Allergen Concentrations in Dust (Fg/g)

Analyte	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Dermatophagoides pteronyssinus	All	195769	187	5.7	0.22		
	Port	69447	129	3.9	0.21		
	Trad	126322	58	6.7	0.23		
Dermatophagoides farinae	All	195769	187	8.7	0.34		0.91
	Port	69447	129	6.7	0.22		0.20
	Trad	126322	58	9.8	0.41		1.57
Canis f1	All	195769	187	56.2	1.93	0.43	3.89
	Port	69447	129	52.2	1.07	0.41	4.18
	Trad	126322	58	58.4	2.39	0.45	3.85
Felis d1	All	195769	187	73.7	0.53	0.26	1.80
	Port	69447	129	74.5	0.46	0.24	1.58
	Trad	126322	58	73.2	0.57	0.28	1.75
Blatella germanica	All	195769	187	0.7	1.00		
	Port	69447	129	0.6	1.00		
	Trad	126322	58	0.8	1.00		

Note: Dust particles <500µm.
Note: Blank cells indicate cases where the percentile could not be estimated.

3.16 Indoor Environmental Quality: Pesticides

Table 3-29 provides a summary of the floor-dust pesticide concentration and loading data for 20 different pesticides. The left-hand portion of the table shows concentration results and the right-hand portion shows loading results. These summary statistics, like the metals, were not population-weighted, but were weighted to reflect the classrooms in those sample schools for which data were available. Four of the pesticides were rarely detected (less than 10% detected) – malathion, lindane, resmethrin, and cyfluthrin. On the other hand, six were detected in over 80% of the samples – chlorpyrifos, cis- and trans-permethrin, o-phenylphenol, piperonyl butoxide, and esfenvalerate. Esfenvalerate had the highest median loading level (0.34 ng/cm^2), while many of the chemicals had median loading levels less than 0.01 ng/cm^2. Examination of the 95th percentiles of the concentration measurements in Table 3-29 showed that nine of the pesticides had measured 95th percentiles above 1.0 Fg/g – chlorpyrifos, cis- and trans-permethrin, resmethrin, piperonyl butoxide, cyfluthrin, cypermethrin, esfenvalerate, and delta-tralomethrin.

In terms of median concentrations, four of the pesticides had higher levels in the traditional classrooms, and three had higher levels in the composite portable classroom samples – (cis- and trans-permethrin, and esfenvalerate). Using the 95th percentile of the distribution as basis of comparison, thirteen pesticides were higher in the traditional classrooms and five pesticides were higher in the portable classroom samples (malathion, propetamphos, resmethrin, cyfluthrin, and delta-tralomethrin). Nevertheless, no statistically significant differences between the means for the portable and traditional classrooms were found for either the concentrations or the loadings.

Table 3-29. Summary of Pesticide Concentrations and Loadings in Floor Dust

		Concentrations (Fg/g)					Loadings (ng/cm^2)				
Analyte	Loc	n	Pct. Meas.	Mean	50th Pctl	95th Pctl	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Diazinon	A	71	57.6	0.358	0.035	0.679	53.000	58.5	0.027	0.002	0.112
	P	36	47.9	0.126	0.003	0.508	26.000	45.9	0.024	0.001	0.175
	T	35	63.1	0.490	0.037	0.634	27.000	65.2	0.028	0.003	0.076
Malathion	A	76	4.5	0.007	0.003	0.004	56.000	3.5	0.001	0.000	0.003
	P	39	7.3	0.010	0.003	0.056	29.000	2.6	0.001	0.001	0.003
	T	37	2.9	0.005	0.003	0.003	27.000	4.0	0.001	0.000	0.002
Chlorpyrifos	A	30	97.0	0.607	0.308	1.906	26.000	96.5	0.088	0.033	
	P	15	91.7	0.636	0.119		12.000	89.3	0.091	0.028	
	T	15	100.0	0.591	0.365	1.384	14.000	100.0	0.086	0.045	
4,4'-DDE	A	74	54.0	0.017	0.008	0.052	54.000	52.7	0.002	0.000	0.009
	P	38	48.1	0.010	0.000	0.043	28.000	40.6	0.002	0.000	0.009
	T	36	57.5	0.022	0.008	0.057	26.000	59.9	0.003	0.000	0.012
Dieldrin	A	75	24.3	0.028		0.154	57.000	25.4	0.004		0.026
	P	37	13.2	0.014		0.070	29.000	17.0	0.002		0.014
	T	38	30.3	0.035		0.164	28.000	30.0	0.004		0.036
cis-Permethrin	A	77	98.6	0.643	0.256	1.870	57.000	98.1	0.095	0.019	0.461
	P	39	100.0	0.329	0.279	0.766	29.000	100.0	0.067	0.026	0.263
	T	38	97.8	0.817	0.226	3.911	28.000	97.1	0.111	0.017	0.567
trans-Permethrin	A	63	100.0	0.691	0.320	2.329	47.000	100.0	0.133	0.037	0.630
	P	36	100.0	0.498	0.381	1.038	27.000	100.0	0.116	0.047	0.483
	T	27	100.0	0.829	0.300	2.865	20.000	100.0	0.146	0.033	0.742
Lindane	A	74	2.1	0.001	0.001	0.001	55.000	1.3	0.000	0.000	0.000
	P	38	5.8	0.002	0.001	0.004	29.000	3.6	0.001	0.000	0.001
	T	36	0.0	0.001	0.001	0.001	26.000	0.0	0.000	0.000	0.000
Pendimethalin	A	44	15.6	0.078	0.005	0.390	34.000	13.8	0.002	0.001	0.011
	P	19	7.1	0.034	0.005	0.163	14.000	2.6	0.001	0.001	0.002
	T	25	19.2	0.097	0.005	0.356	20.000	18.0	0.003	0.001	
Propoxur	A	38	69.3	0.129	0.014	0.633	27.000	65.6	0.024	0.002	0.087
	P	19	77.1	0.128	0.014		15.000	80.5	0.025	0.003	
	T	19	64.5	0.129	0.013		12.000	53.9	0.023	0.001	
o-Phenylphenol	A	77	100.0	0.155	0.063	0.486	57.000	100.0	0.015	0.007	0.087
	P	39	100.0	0.086	0.060	0.249	29.000	100.0	0.014	0.008	0.036
	T	38	100.0	0.193	0.065	0.505	28.000	100.0	0.015	0.006	0.095

		Concentrations (μg/g)					Loadings (ng/cm^2)				
Analyte	Loc	n	Pct. Meas.	Mean	50th Pctl	95th Pctl	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Propetamphos	A	69	12.7	0.009	0.001	0.066	50.000	8.5	0.002	0.000	0.003
	P	36	16.1	0.012	0.001	0.078	26.000	16.2	0.002	0.000	0.008
	T	33	10.6	0.008	0.001	0.058	24.000	3.8	0.002	0.000	0.001
Resmethrin	A	76	2.9	0.098			56.000	4.0	0.014		
	P	38	6.6	0.221		1.938	28.000	9.1	0.039		0.169
	T	38	0.9	0.032			28.000	1.3	0.001		
Piperonyl Butoxide	A	63	93.3	0.629	0.369	2.195	48.000	94.1	0.101	0.038	0.376
	P	34	90.8	0.343	0.265		26.000	87.9	0.053	0.024	0.201
	T	29	94.8	0.801	0.390	3.230	22.000	97.7	0.130	0.036	0.450
Bifenthrin	A	71	28.7	0.134		0.627	53.000	33.0	0.017		0.099
	P	38	29.2	0.157		0.311	28.000	32.6	0.009		0.045
	T	33	28.5	0.119		0.684	25.000	33.3	0.022		0.146
Cyhalothrin	A	77	25.5	0.081	0.001	0.216	57.000	20.9	0.008	0.000	0.031
	P	39	18.0	0.098	0.001	0.142	29.000	11.8	0.007	0.000	0.033
	T	38	29.7	0.071	0.001	0.217	28.000	26.0	0.009	0.000	0.023
Cyfluthrin	A	74	9.5	0.297		2.586	54.000	8.1	0.022		0.223
	P	38	14.7	0.301		1.797	28.000	16.0	0.039		
	T	36	6.5	0.295		1.335	26.000	3.5	0.012		
Cypermethrin	A	75	12.4	0.178		1.401	55.000	12.6	0.027		0.193
	P	39	20.9	0.208		1.248	29.000	16.7	0.029		0.157
	T	36	7.3	0.161		1.418	26.000	10.2	0.025		
Esfenvalerate	A	66	87.2	4.488	3.830	11.398	49.000	90.9	0.970	0.341	3.978
	P	32	95.1	4.678	4.019	10.423	24.000	93.2	0.897	0.512	2.963
	T	34	83.1	4.392	3.034	12.310	25.000	89.7	1.006	0.304	3.882
Delta/Tralo-methrin	A	77	35.5	0.292	0.010	1.564	57.000	28.3	0.040	0.001	0.149
	P	39	28.9	0.442	0.010	3.057	29.000	18.7	0.065	0.002	
	T	38	39.2	0.209	0.010	1.561	28.000	33.6	0.026	0.001	0.121

Note: Statistics apply to sample classrooms with data.
Note: Loc=Location (A=all classrooms, P=portable classrooms, T=traditional classrooms).
Note: Blank cells indicate cases where the percentile was not estimated.

3.17 Indoor Environmental Quality: PAHs

Table 3-30, in a format similar to the Table 3-29, furnishes a summary of the floor-dust polynuclear aromatic hydrocarbon data for sixteen PAHs. Although most of the PAHs were detected in over 50% of the classroom samples, the concentrations were generally very low. Only five of the PAHs had measured concentrations above 1.0 μg/g (chrysene, fluoranthene, pyrene, Indeno[1,2,3-cd]pyrene, perylene/benzo[b]fluoranthene). Chrysene, benzo[k]fluoranthene, fluoranthene, phenanthrene, pyrene, naphthalene, fluorene, benzo[g,h,i]perylene, and

Table 3-30. Summary of PAH Concentrations and Loadings in Floor Dust

		Concentrations (Fg/g)					Loadings (ng/cm^2)				
Analyte	Loc	n	Pct. Meas.	Mean	50th Pctl	95th Pctl	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Benzo[a]pyrene*	A	69	58.6	0.115	0.054	0.306	51.000	63.4	0.018	0.008	0.064
	P	35	75.5	0.141	0.072	0.485	26.000	85.5	0.026	0.012	0.065
	T	34	49.3	0.100	0.001	0.290	25.000	51.1	0.013	0.001	0.044
Benzo[a]anthracene*	A	71	79.1	0.166	0.053	0.329	53.000	82.6	0.022	0.005	0.062
	P	37	94.3	0.242	0.064	0.592	28.000	94.0	0.034	0.008	0.104
	T	34	70.0	0.121	0.039	0.166	25.000	75.8	0.015	0.005	0.018
Acenaphthylene	A	53	51.7	0.020	0.002		40.000	58.0	0.003	0.001	0.013
	P	29	39.3	0.012	0.000	0.049	22.000	36.1	0.002	0.000	0.011
	T	24	59.4	0.025	0.005		18.000	71.7	0.004	0.001	
Anthracene	A	69	73.5	0.040	0.007	0.182	52.000	72.5	0.004	0.001	0.006
	P	36	72.8	0.040	0.008	0.199	26.000	72.4	0.006	0.001	0.015
	T	33	74.0	0.040	0.007	0.035	26.000	72.6	0.004	0.001	0.004
Chrysene*	A	75	92.9	0.305	0.149	0.678	55.000	96.7	0.047	0.019	0.199
	P	39	97.1	0.404	0.152	1.012	29.000	97.7	0.074	0.028	0.267
	T	36	90.5	0.247	0.130	0.553	26.000	96.2	0.032	0.014	0.086
Benzo[k]fluoranthene*	A	74	80.0	0.170	0.057	0.378	54.000	80.4	0.023	0.006	0.054
	P	38	90.1	0.239	0.062	0.624	28.000	89.9	0.036	0.012	0.111
	T	36	74.2	0.131	0.053	0.199	26.000	75.0	0.016	0.004	0.024
Fluoranthene	A	76	100.0	0.414	0.184	0.965	56.000	100.0	0.062	0.018	0.239
	P	39	100.0	0.559	0.197	1.360	29.000	100.0	0.094	0.035	0.323
	T	37	100.0	0.332	0.160	0.815	27.000	100.0	0.045	0.015	0.148
Phenanthrene	A	76	100.0	0.375	0.173	0.574	56.000	100.0	0.052	0.024	0.153
	P	39	100.0	0.407	0.172	0.717	29.000	100.0	0.067	0.024	0.182
	T	37	100.0	0.357	0.174	0.564	27.000	100.0	0.044	0.023	0.120
Pyrene	A	76	100.0	0.528	0.201	1.000	56.000	100.0	0.076	0.022	0.319
	P	39	100.0	0.614	0.215	1.457	29.000	100.0	0.098	0.036	0.321
	T	37	100.0	0.480	0.198	0.976	27.000	100.0	0.063	0.020	0.223
Indeno[1,2,3-cd]pyrene	A	74	68.2	0.308	0.049	0.357	56.000	62.6	0.043	0.003	0.097
	P	38	84.6	0.439	0.052	1.178	29.000	83.0	0.066	0.010	0.195
	T	36	58.9	0.233	0.026	0.261	27.000	51.2	0.029	0.002	0.040
Naphthalene	A	69	100.0	0.018	0.014	0.044	52.000	100.0	0.003	0.002	0.008
	P	36	100.0	0.017	0.013	0.038	27.000	100.0	0.004	0.002	0.009
	T	33	100.0	0.019	0.014	0.043	25.000	100.0	0.002	0.002	0.007

		Concentrations (Fg/g)					Loadings (ng/cm^2)				
Analyte	Loc	n	Pct. Meas.	Mean	50th Pctl	95th Pctl	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Fluorene	A	73	100.0	0.047	0.030	0.063	53.000	100.0	0.007	0.004	0.025
	P	38	100.0	0.043	0.027	0.067	28.000	100.0	0.008	0.004	0.020
	T	35	100.0	0.049	0.031	0.062	25.000	100.0	0.007	0.004	0.023
Acenaphthene	A	66	27.2	0.016		0.014	49.000	31.4	0.002		0.002
	P	33	23.7	0.019		0.053	25.000	22.9	0.003		0.008
	T	33	29.1	0.015		0.014	24.000	36.4	0.002		0.002
Dibenz[a,h]anthracene*	A	69	41.4	0.050	0.003	0.081	49.000	36.1	0.007	0.000	0.027
	P	35	57.9	0.081	0.014	0.305	25.000	59.8	0.013	0.001	0.043
	T	34	32.9	0.034	0.002	0.055	24.000	24.0	0.004	0.000	0.006
Benzo[g,h,i]perylene*	A	75	94.0	0.218	0.111	0.390	56.000	96.3	0.034	0.015	0.134
	P	38	94.6	0.281	0.123	0.822	29.000	96.7	0.051	0.019	0.163
	T	37	93.6	0.182	0.103	0.341	27.000	96.1	0.025	0.014	0.065
Perylene/Benzo[b]fluoranthene	A	71	91.4	0.453	0.294	1.078	54.000	94.9	0.080	0.033	0.384
	P	36	93.2	0.646	0.241	1.852	28.000	91.1	0.122	0.043	0.414
	T	35	90.5	0.351	0.311	0.916	26.000	97.0	0.057	0.029	0.161

Note: Statistics apply to sample classrooms with data.
Note: Loc=Location (A=all classrooms, P=portable classrooms, T=traditional classrooms).
* Differences in mean *loadings* between portables and traditionals are statistically significant (p=0.05).
Note: Blank cells indicate cases where the percentile could not be estimated.

perylene/benzo[b]fluoranthene (co-elution) were all detected in over 80% of the samples. No statistically significant differences between the means for the portable and traditional classrooms were found for the concentration data; however, six of the chemicals had significantly higher (p=0.05) mean loadings for the portables than for the traditionals: benzo[a]pyrene, benzo[a]anthracene, chrysene, benzo[k]fluoranthene, benzo[g,h,i]perylene, and dibenz[a,h]anthracene.

Median traditional-classroom concentrations were higher than median portable-classroom concentrations for two PAHs (fluorene and perylene/benzo[b]fluoranthene), whereas nine of the PAHs had higher median concentrations in the composite portable classroom samples. A comparison of the 95th percentiles of the concentration distributions indicated that fifteen of the sixteen PAHs were higher in the portable classrooms. (Naphthalene was measured at equal concentration levels in both types of classrooms.)

3.18 Factors Affecting Indoor Environmental Quality

3.18.1 Modeling Strategy

As an initial effort towards identifying factors affecting IEQ, a series of weighted regression models were fit that related an IEQ variable, Y, to classroom type (portable/traditional indicator) and to other variates. Model inputs were defined as follows:

- R = classroom type indicator (= 1 if portable, = 0 otherwise),
- Z = an outdoor measure corresponding to Y. For example, if Y is the logarithm of the classroom formaldehyde levels, then Z would be the logarithm of the outdoor formaldehyde levels at the schools. (Log-scaled Y variates are used since measurement error variability is generally expected to be larger for higher levels than for lower levels. For example, if there is a constant relative standard deviation, then the log-scaled variates would be expected to have homogeneous measurement-error variance.)
- X and X2 =other potential independent variables. These can be continuous variates or can be discrete variates that are coded as a set of dummy (0,1) variables. The models are structured and denoted as follows:

Three different modeling structures were employed (see Section 2.9 for more detail), as depicted below:

Structure	Model A Terms			Additional Terms In Model B	Additional Terms In Model C
1	R			X	X2
2	R	Z		X	X2
3	R*	Z*	ZR	X	X2

* Since Structure 3 is used to determine if the effect of Z differs for portables and traditionals (i.e., to determine if the ZR term is significant), separate tests for R and Z within Structure 3 are not possible.

As indicated above, the models are identified by letter and structure; for instance, the model containing R, Z, and a single X would be referred to as Model B2. For cases in which there is not an outdoor measurement analogous to Y, only structure 1 is used. For the present study, all of the C models considered contained CLAGE (classroom age, in years) plus one other candidate predictor. Thus a C model would be chosen if <u>both</u> CLAGE and the second predictor variate were statistically significant, a B model would be chosen if only one of the two was statistically significant, and an A model would be chosen if neither was statistically significant. <u>All tests used for selecting models were based on 0.05 significance levels</u>.

Appendix G provides the details of the modeling results. It consists of five parts:

Part 1: An index to the X variables (not all Xs go with all Ys)
Part 2: An index to the X variables and their levels
Part 3: P-values for the Wald F tests associated with the A and B models.
Part 4: P-values for the Wald F tests associated with the C models.
Part 5. Identification of the Preferred Models.

The basic strategy for choosing a model is described in Appendix G, and below:

- The preferred A model for a given Y is first determined as follows. If the ZR term is significant, then Model A3 is preferred over A1 or A2. If not, but the Z term is significant, then Model A2 is the preferred model. If neither Z nor ZR is significant, then Model A1 is preferred.

- The preferred B model for each Y and X combination is determined, using the same logic as above. If the X variate is not significant, then one of the A models is preferred over the B models.
- The preferred C model for each Y, X, and X2 combination is determined, using the same logic as above. One of the A or B models is preferred over the C models except when both X and X2 are statistically significant. (Only C models in which X is the classroom age have been attempted at this point.)
- The overall preferred model is chosen as follows. If both classroom age (CLAGE) and the X2 variable are statistically significant, then the C model is chosen. On the other hand, if only the X variable is statistically significant, then the B model would be chosen. If neither X nor CLAGE are significant, then the A Model is chosen if it has any significant effects. If not, no preferred model is chosen.

3.18.2 Factors Affecting Pollen/Spores

Models for the following Y variables were estimated:

$Y1 = \log_{10}$ (Pollen Count)
$Y2 = \log_{10}$ (Total Fungal Spores).

Independent variables (X or X2) that were examined as potential predictors are listed in Table 3-31, which gives the following:

- the variable name,
- the source of variable (e.g., the original questionnaire variable(s) from which it was derived),
- the description of the variable,
- the definitions of the levels of the predictors.
- Dependent variables (Y) that were modeled appear as headings of the last two columns. An entry in a given Y1 or Y2 column indicates that the candidate predictor in that row was examined for that particular Y. If the model type is A1, A2, or A3, then the predictor was deemed to be not statistically significant.[4] With one exception, this was the case for the pollen count and total fungal spores models. Therefore, for the candidate predictors that were examined, the following conclusions can be reached:
  - There was a statistically significant association between indoor and outdoor levels (since structure 2 was chosen) for both Y1 and Y2. Reference to the selected specific modeling results appearing in Appendix H indicated that the association is truly positive – i.e., higher outdoor levels were associated with higher indoor levels.
  - The tests for significance of the classroom-type effect (R) are summarized in Appendix G. They indicate that the portable and traditional classrooms were not significantly different in terms of their Y1 and Y2 levels.

[4] Except where noted, significance was judged using a 0.05 level. Other associations of interest may be found by examining the specific p-values given in Appendix G.

Table 3-31. Selected Models for Pollen Counts and Total Fungal Spores

Variable Name	Source Variable(s)	Description	Level 1	Level 2	Level 3	Level 4	Y1	Y2
AI2	AI2	Windows open today	Yes	No			B2	
CAIROK	TQ2c	Classroom air (teacher)	Yes	No			A2	
CARPET	AC2_02,07	Carpet/rugs on floor	Yes	No			A2	A2
CEILMOLD	AB6	Mold areas on ceiling	Some	None				A2
CLAGE	CA3,CA1	Classroom Age	continuous				A2	A2
CWATSTAN	AB5	Water stains on ceiling	Yes	No				A2
DRNFAIL	BD13_1,2,10	Drain test failure	Yes	No	NA			A2
FLTRGAP	BG6	Size of gap around filter	>=1/2in.	<1/2in.	None	DK/NA	A2	
FWATSTAN	AC7	Water stains on floor	Yes	No				A2
LCO2CONC	Q-Trak	Log Avg Indr Air CO2 Conc	continuous				A2	A2
MOISTA	BB5a-f	Max wall, ceiling floor moisture (%)	Max=0	Max>0				A2
MOLDAREA	AF11	Mold areas	Some	None				A2
MUSTODOR	TQ5a	Musty odor at times (teacher)	Yes	No				A2
REGION	Sample Frame	Geographic region	North	South			A2	A2
RFQ16B	RFQ16b	Freq of vacuuming/sweeping/dusting	5/wk	3-4/wk	Other		A2	
SCHTYP	Sample Frame	School type	Elem	Middle	High		A2	
TURNOFF	TQ4	Turn off heat/AC due to noise (teacher)	Yes	No			A2	
URBAN	Sampling Fram	Urban School	Yes	No			A2	
WATRLEAK	TQ6a	Leak or flood in room (teacher)	Current	Previous	Never	Unknown		A2

Y1 = $\log_{10}$ (Pollen Count)
Y2 = $\log_{10}$ (Total Fungal Spores)
Entries in the Y1 and Y2 columns indicate the preferred model. Blanks in these columns indicate that the independent variable was not modeled.
Portable and traditional classrooms are not significantly different at the 0.05 level.

- The tests for significance for the candidate predictors (see Appendix G) revealed only one X with statistical significance – namely “windows open” (for Y1). Reference to the detailed modeling results in Appendix H shows that classrooms with “windows open today” tended to have lower pollen counts (statistically significant to 0.05 level of significance).
- The B2 model, which included “windows open today” and the outdoor pollen count covariate, accounted for 17% of the total variation in the indoor levels.
- For the total fungal spores models, the classroom age effect in the C-type models was not significant; hence these models were not selected. However, there were several X factors that did appear significant ($p<0.10$) in those models – namely, water stains on the floor, ceiling mold, and mold areas.

3.18.3 Factors Affecting Indoor-Air Aldehyde Concentrations

Models for the following Y variables were estimated[5]:

Y1=log(Formaldehyde Concentration)
Y2=log(Acetaldehyde Concentration)
Y3=log(o,p-tolualdehyde Concentration.

Independent variables (X or X2) that were examined as potential predictors are listed in Table 3-32, which is structured like the previous table.

Selected models for the three species were quite different. For formaldehyde, the type of classroom was generally statistically significant, with portables having higher levels (i.e., a positive coefficient on the portable/traditional indicator variable, as evidenced in Appendix H). The other two aldehydes showed no classroom type effect; however, the tolualdehyde models showed a significant outdoor-air by room-type interaction. These two aldehydes also showed significant associations with their outdoor levels, while the formaldehyde models generally did not show a relationship with the outdoor levels.

Two variables showed the strongest positive relationships with indoor formaldehyde levels: indoor CO_2 (adjusted for outdoor air formaldehyde levels and classroom type) and indoor relative humidity (adjusted for classroom type). These two models accounted for 22% and 32%, respectively, of the total variation in the indoor levels (See Appendix H).

The formaldehyde model including “pressed wood bookcases” as an X indicator, which also included a significant classroom age variate (positive slope), accounted for only about 14% of the total variation in the indoor formaldehyde levels. However, the effect of this X indicator was 0.304, implying about a 30% increase in formaldehyde levels when pressed wood bookcases were present, and the effect of classroom type was 0.288, implying that portables’ levels were about 30% higher than traditionals. The positive slope for the classroom age variable in this model appears to be driven largely by the lower formaldehyde levels in newer traditionals. This is demonstrated by the (weighted) formaldehyde means shown in Table 3-33 for portables and traditionals of different ages:

[5] Except when explicitly indicated as $\log_{10}$, all logarithms are natural (base e) logarithms.

Table 3-32. Selected Models for Selected Aldehydes

Variable Name	Source Variable(s)	Description	Level 1	Level 2	Level 3	Level 4	Y1
AE11_03	AE11_03	Bookcase -- pressed wood	Yes	No			C1*
BORDWALL	AD1_02,07	Fiber/particle board or plywood walls	Yes	No			A1*
CLAGE	CA3,CA1	Classroom Age	continuous				B1*
FRESHNER	AE6_05	Air freshener	Some	None			B1*
GENINST	AA13	General instruction classroom	Yes	No			B1*
LCO2CONC	Q-Trak	Log Avg Indr Air CO2 Conc	continuous				B2*
RELHUM	Q-Trak	Avg Indoor Rel Humidity	continuous				B1
SCHTYP	Sample Frame	School type	Elem	Middle	High		A1*
TAKWALL	AD1_01	Tackboard walls	Yes	No			A1*
TEMP	Q-Trak	Avg Indoor Temp	continuous				A1*

Y1 = log Formaldehyde Concentration
Y2 = log Acetaldehyde Concentration
Y3 = log o,p-tolualdehyde Concentration
*Portable and traditional classrooms are significantly different (p=0.05).
Entries in the Y1, Y2, and Y3 columns indicate the preferred model.

Table 3-33. Mean Indoor Formaldehyde Concentrations, by Age and Classroom Type (ppb)

Location	Classroom Age (yrs)				
	0-3	4-5	6-10	11-15	16+
Portables, ppb (n):	17.8 (14)	13.9 (23)	16.9 (15)	14.0 (17)	14.0 (24)
Traditionals, ppb (n):	9.4 (10)				13.4 (33)

Unfortunately, separating the effects of age and room type was not feasible, because the age distributions of the two types of rooms were so disparate (see Table 3-11) and because the sample size for newer traditionals was so small (only 2 were less than 4 years old and only 10 were less than 16 years old). Use of air fresheners was another X variate that appeared statistically significant for formaldehyde; a similar association was seen in Phase I.

The model for acetaldehyde that included “pressed wood bookcases” as an X indicator accounted for about 24% of the total variation in the indoor levels of that analyte. The effect for this X variate was 0.131, indicating a significant increase in the indoor levels when the pressed wood was present, but one that was not as large (relative) as for formaldehyde. Indoor relative humidity was also strongly associated with indoor acetaldehyde levels.

Additional details for selected aldehyde models are given in Appendix H.

3.18.4 Factors Affecting Indoor-Air VOC Concentrations

Models were fit for five VOCs, using the candidate predictors given in Table 3-34. The dependent variables included benzene plus the four identified in the right hand columns of the table. Benzene is not shown because no significant effects of any kind were normally detected for that analyte (p=0.05). The C1 model for benzene that included classroom age (positive association, p=0.07) and "presence of carpet/rugs" (positive association, p=0.04) did account for about 21% of variability in indoor benzene levels (see Appendix H). For the VOCs indicated in Table 3-34, there were associations with outdoor levels in virtually all cases (i.e., mostly structures 2 and 3), and these associations appeared somewhat stronger than for the aldehydes. Few of the candidate X predictors were found to be significant. Most of the toluene and m,p-xylene models required structure 3, indicating that the outdoor association varied by classroom type. The toluene model (as well as some others, such as the o,p-tolualdehye) showed no relation with outdoor levels for portables and a positive relation for traditional classrooms.

A number of the significant associations with the X variables are counter-intuitive. For example, for tetrachloroethylene, a significant negative association with presence of carpet/rugs was detected, perhaps reflecting a sink, or removal effect by carpet and carpet padding. For toluene, significantly lower levels were estimated when new construction/repair activities were on-going; this, of course, could reflect the fact that doors and windows might be more frequently closed when those activities were outside of the immediate classroom. The variables in this model accounted for 69% of the total variation in indoor toluene levels.

Additional details for selected VOC models are given in Appendix H.

Table 3-34. Selected Models for Selected VOCs

Variable Name	Source Variable(s)	Description	Level 1	Level 2	Level 3	Level 4	Y1	Y2	Y3	Y4
ACTVOUT	AG1_01,02	New construction/repairs affecting IAQ	Yes	No			A2	A2	C3	A3
AG8_01	AG8_01	Parking lot/roadway within 50 ft.	Yes	No			A2	A2	A3	A3
CARPET	AC2_02,07	Carpet/rugs on floor	Yes	No			A2	B2	A3	A3
CHEMPROD	AE17_11	Chemical products	Some	None			A2	A2	A3	A3
CLAGE	CA3,CA1	Classroom Age	continuous				A2	A2	A3	A3
FRESHNER	AE6_05	Air freshener	Some	None			A2	A2	A3	A3
GENINST	AA13	General instruction classroom	Yes	No			A2	B2	A3	A3
LCO2CONC	Q-Trak	Log Avg Indr Air CO2 Conc	continuous				B3	A2	A3	B1
SCHTYP	Sample Frame	School type	Elem	Middle	High		B2	A2	A3	A3
TEMP	Q-Trak	Avg Indoor Temp	continuous				A2	A2	A3	C1

Y1 = log Chloroform
Y2 = log Tetrachloroethylene
Y3 = log Toluene
Y4 = log m, p-Xylene Concentration
Entries in the last 4 columns indicate the preferred model.
Portable and traditional classrooms are not significantly different at the 0.05 level.

3.18.5 Factors Affecting Indoor-Air CO_2 Concentrations

Two of the summary CO_2 measures were modeled: Y1=log(CO_2 Concentration), and Y2=percent of time CO_2 concentrations exceed 1000 ppm. The candidate predictors are listed in Table 3-35. For both Y1 and Y2, classroom age had a significant positive relationship with the CO_2 levels, and for Y1, there was also a significant positive relation with the outdoor levels. (There was not an corresponding outdoor measurement for Y2.) However, the inclusion of the teacher's rating of IAQ in the Y1 model resulted in an interaction effect between classroom type and outdoor CO_2 levels. A positive relation with the outdoor levels remained for the portables, but not for the traditionals. Based on the log(CO_2) model, the indoor CO_2 levels were estimated to be approximately 30% lower (coefficient on that X was -0.273) when the teachers reported that the IAQ was acceptable. The Y1 and Y2 models both showed a significant effect of school type, with high schools having the highest indoor CO_2 levels. See Appendix H for more details on selected models.

3.18.6 Factors Affecting Indoor-Air Particle Counts

Models for the following Y variables were estimated:

Y1 = log (average number of particles/minute # 2.5 Fm)
Y2 = log (average number of particles/minute # 10 Fm).

Independent variables (X or X2) that were examined as potential predictors are listed in Table 3-36. With the exception of one model, none of the predictors (including classroom age) was statistically significant. Also the room type indicator was not significant except in that one case. The exception was for $PM_{2.5}$; when "presence of carpet rugs" was used as a predictor, then both that predictor and the classroom indicator were statistically significant. Rooms with carpets/rugs and traditional classrooms had lower levels. (See Appendix H for details.) A number of the B- and C-type models (which were not selected because of non-significant X variates) showed significant room-type by outdoor-level interactions; this interaction effect was significant for both $PM_{2.5}$ and PM_{10} at the 0.07 significance level for model A3.

3.18.7 Factors Affecting Noise Associated with HVACs

A single variate was modeled: Y1=the noise level (dBA) measured near the register when the HVAC unit was on. Table 3-37 lists the candidate predictors. In this case, only model structure 1 is relevant since there is no corresponding outdoor measure. Of the candidate X predictors, only classroom age was statistically significant. For that model, classroom age had a positive effect (older rooms had higher noise levels) and the portables had significantly higher noise levels than the traditionals. This model only accounted for only about 11% of the total variation in theY1 measure, however. (See Appendix H.)

Table 3-35. Selected Models for CO_2 Measures

Variable Name	Source Variable(s)	Description	Level 1	Level 2	Level 3	Level 4	Y1	Y2
AG8_01	AG8_01	Parking lot/roadway within 50 ft.	Yes	No			none	none
AHUAXS	BG1	Ease of Access to AHU interior	Good	Fair	Poor/None		none	none
CAIROK	TQ2c	Classroom air (teacher)	Yes	No			C3	C1
CLAGE	CA3,CA1	Classroom Age	continuous				B3	B1*
HVACMODE	BB2	HVAC mode	Heating	Cooling	Fan Only		none	none
OAPERS	BB4_C,AA11	Outdoor air flow/person	continuous				none	none
REGION	Sample Frame	Geographic region	North	South			none	none
SCHTYP	Sample Frame	School type	Elem	Middle	High		C3	C1*
TAIRPERS	BB4_D&_E,AA11	Supply air flow cfm/person	continuous				none	none
TURNOFF	TQ4	Turn off heat/AC due to noise (teacher)	Yes	No			none	none
USETOL	FQ19a,b	Awareness/use of EPA IAQ Tools	Aware/yes	Aware/no	Aware/DK	Unaware	none	none

Y1 = log (average CO_2 concentration)
Y2 = % of time CO_2 >1000 ppm
Entries in the Y1 and Y2 columns indicate the preferred model.
* Portable and traditional classrooms are significantly different (p=0.05).

Table 3-36. Selected Models for Number of Particles

Variable Name	Source Variable(s)	Description	Level 1	Level 2	Level 3	Level 4	Y1	Y2
ACTVOUT	AG1_01,02	New construction/repairs affecting IAQ	Yes	No			A2	A2
AG8_01	AG8_01	Parking lot/roadway within 50 ft.	Yes	No			A2	A2
AHUAXS	BG1	Ease of access to AHU interior	Good	Fair	Poor/None		A2	A2
CARPET	AC2_02,07	Carpet/rugs on floor	Yes	No			B2*	A2
CLAGE	CA3,CA1	Classroom Age	continuous				A2	A2
DUSTMAT	AG6,AC3	Walk-off dust mats	yes	No			A2	A2
FLTRGAP	BG6	Size of gap around filter	>=1/2in.	<1/2in.	None	DK/NA	A2	A2
FLTRLDG	BG5	Dirt loading on filter	Heavy	Medium	Light	DK/NA	A2	A2
LCO2CONC	Q-Trak	Log Avg Indr Air CO2 Conc	continuous				A2	A2
RFQ16B	RFQ16b	Freq of vacuuming/sweeping/dusting	5/wk	3-4/wk	Other		A2	A2
SCHTYP	Sample Frame	School type	Elem	Middle	High		A2	A2

Y1 = Particles/min <=2.5µm
Y2 = Particles/min <=10µm
Entries in the Y1 and Y2 columns indicate the preferred model.
* Portable and traditional classrooms are significantly different (p=0.05).

Table 3-37. Selected Models for Noise Measure (near Register with HVAC on)

Variable Name	Source Variable(s)	Description	Level 1	Level 2	Level 3	Level 4	Y1
AHUAXS	BG1	Ease of access to AHU interior	Good	Fair	Poor/None		none
CAIROK	TQ2c	Classroom air (teacher)	Yes	No			none
CLAGE	CA3,CA1	Classroom Age	continuous				B1*
LCO2CONC	Q-Trak	Log Avg Indr Air CO2 Conc	continuous				none
RBC4	BC4	Air handling unit location	Wall	Window	Rooftop	Other/NA	none
SCHTYP	Sample Frame	School type	Elem	Middle	High		none
TOTSAIR	BB4_D&_E	Supply air flow (cfm)	continuous				none
TURNOFF	TQ4	Turn off heat/AC due to noise (teacher)	Yes	No			none
URBAN	Sampling Frame	Urban School	Yes	No			none

Y1 = Noise (dBA) near register with HVAC on.
Entries in the Y1 column indicate the preferred model.
* Portable and traditional classrooms significantly different (p=0.05).

3.18.8 Factors Affecting Indoor Temperatures

Two types of temperature measures were modeled:

Y1=percent of time that the room was below 20°C (too cool)
Y2=percent of time that the room was above 23°C (too warm).

The candidate predictors are shown in Table 3-38. For Y2, only two predictors appeared significant (school type, and awareness and use of EPA IAQ Tools). A meaningful pattern for the latter X variable was not apparent, however, for either Y1 or Y2. Portables and traditionals were not different for Y2, but were significantly different for Y1. The percent of time that the portables had less than 20°C (68°F) temperatures was larger (by about 12%) than for the traditional classrooms. Appendix H furnishes more details.

3.19 IEQ Results for Specially Selected Schools

Formaldehyde. As described in Section 2.4.1, 14 schools were specially selected for participation in Phase II based on their Phase I data. In particular, each of these schools had at least two reports of indoor environmental quality problems (e.g., high formaldehyde or observed mold) in Phase I. Thirteen of these schools participated in Phase II of the study. Summary statistics regarding the indoor and outdoor formaldehyde concentrations at these schools in Phase II are reported in Table 3-39.

Comparison with the results for the entire Phase II sample, reported in Table 3-23, shows that the mean formaldehyde concentrations at the specially selected schools are remarkably similar to those for the entire Phase II sample. Moreover, the maximum formaldehyde concentrations observed at these schools are remarkably similar to the estimated 95th percentile concentrations for the population as a whole.

Carbon Dioxide. As indicated in Table 3-18, the mean percentage of time that indoor CO_2 levels exceeded 1000 ppm was estimated for the general population of eligible classrooms to be 42.8% (42.1% for portables). The corresponding mean for the classrooms in the specially-selected schools was 24.0% (32.1% in portable classrooms).

Surface swabs. As described in Section 2.5.3, cotton swab surface samples were collected only in the specially selected schools. They were collected in the classroom during the lunch period when the classroom was vacant. The cotton swab samples were collected only from surfaces (e.g., window sill or door knob) where microbiological growth could be visually determined. In some classrooms, swab samples were collected from more than one surface. The swabs were cultured in the laboratory, and the results are reported in Table 3-40 for each of the swab samples in units of the logarithm (base 10) of the numbers of colony forming units (CFUs) per swab.

Culturable Airborne Microorganisms. As described in Section 2.5.3, Mattsen-Garvin (M-G) bioaerosol samples were collected in the classrooms and outdoors at the specially selected schools. The indoor Mattsen-Garvin samples were collected in the classroom during the lunch period when the classroom was vacant. The M-G samples were collected on Petri dishes and cultured in the laboratory. The results are reported in Appendix E and are summarized in Table 3-41 for both the indoor and outdoor samples in units of logarithm (base 10) of the CFUs per cubic meter of air. Since these data were collected only at the specially selected schools, the data are not weighted and formal tests of hypotheses are not warranted.

Other IEQ Characteristics. Comparison of the classrooms in the specially-selected schools with the general population of eligible classrooms showed that the former were reported to have more moisture-related problems. For instance, teachers reported “musty odors at times” in 92.4% of the specially-selected classrooms (93.6% for portables), as contrasted with 64.2% for the general population (66.6% for portables). Mold areas were reported (Classroom Form) in 7.6% of the specially-selected schools, as contrasted with only 1.1% for the overall population of eligible classrooms.

Table 3-38. Selected Models for Temperature Measures

Variable Name	Source Variable(s)	Description	Level 1	Level 2	Level 3	Level 4	Y
AHUAXS	BG1	Ease of access to AHU interior	Good	Fair	Poor/None		A1*
CAIROK	TQ2c	Classroom air (teacher)	Yes	No			A1*
CLAGE	CA3,CA1	Classroom Age	continuous				A1*
OAPERS	BB4_C,AA11	Outdoor air flow/person	continuous				A1*
REGION	Sample Frame	Geographic region	North	South			A1*
SCHTYP	Sample Frame	School type	Elem	Middle	High		A1*
TAIRPERS	BB4_D&_E,AA11	Supply air flow cfm/person	continuous				A1*
TURNOFF	TQ4	Turn off heat/AC due to noise (teacher)	Yes	No			A1*
USETOL	FQ19a,b	Awareness/use of EPA IAQ Tools	Aware/yes	Aware/no	Aware/DK	Unaware	B1*

Y1 = % time temp <20°C.
Y2 = % time temp >23°C.
Entries in the Y1 and Y2 columns indicate the preferred model.
* Portable and traditional classrooms significantly different (p=0.05).

Table 3-39. Summary of Formaldehyde Concentrations (ppb)

Location	n	Minimum	Maximum	Mean	Std. Deviation
Outdoor	12	1.0	8.6	3.5	2.7
All classrooms	38	3.4	24.1	15.2	5.2
Portable	28	3.4	24.1	16.1	5.2
Traditional	10	5.4	17.9	12.6	4.3

Table 3-40. List of Culturable Microorganisms Measurements from Surface Samples (log_{10}[CFU/swab

Classroom*	Sampling Site	Aureobasidium spp.	Yeast	Cladosporium spp	Other
1145P1	Desk	0.000	0.000	0.000	0.000
	Vent	0.000	0.000	0.000	1.477
1145P2	Vent	0.000	0.000	0.000	2.204
1145P3	Vent	0.000	0.000	0.000	0.000
1163P1	ceiling tile	0.000	0.000	0.000	0.000
1163P2	ceiling air vent	0.000	0.000	0.000	1.000
1163T3	Decorations	4.147	3.033	3.297	3.000
1236P1	window countertop	0.000	0.000	0.000	0.000
1236P2	air vent	0.000	0.000	1.297	2.301
	window countertop	2.742	0.000	2.455	1.794
1236T3	Doorknob	0.000	0.000	0.000	0.000
1283P1	wall near air vent	4.041	4.568	0.000	3.301
1283P2	Counter near sink	4.448	4.231	0.000	2.964
1283T3	near air vent	0.000	5.532	4.045	4.267
1306P1	from window sill	0.000	5.633	0.000	0.000
1306P2	from window sill	0.000	5.360	0.000	4.785
1306T3	top of cabinet	0.000	4.078	0.000	3.017
1332P1	heat vent	0.000	0.000	0.000	0.000
1332P2	Fan	0.000	0.000	0.000	0.000
	heat vent	0.000	0.000	0.000	0.000
1332T3	computer mouse	0.000	0.000	0.000	0.000
1435P1	Vent	3.462	0.000	0.000	0.000
1435P2	Vent	3.477	3.301	0.000	0.000
1435T3	students desk	0.000	0.000	0.000	0.000
1482P1	taken from ceiling	0.000	0.000	0.000	0.000
1482P2	taken from ceiling	0.000	0.000	0.000	1.602
1482P3	collected from ceiling	0.000	0.000	0.000	1.778
1537P1	Ceiling	3.571	3.358	0.000	0.000
1537P2	Desk	0.000	0.000	0.000	0.000
	Wall	0.000	2.894	0.000	1.380
1537T3	NA	0.000	0.000	0.000	0.000
2162P1	art table	0.000	0.000	0.000	0.000
2162P2	vent from outside	0.000	3.845	0.000	0.000
2162T3	air vent	0.000	0.000	2.845	0.000
	student desk	0.000	0.000	0.000	0.000

Classroom*	Sampling Site	Aureobasidium spp.	Yeast	Cladosporium spp	Other
2178P1	back of room vent	0.000	0.000	0.000	0.000
2178P2	Doorhandle	0.000	0.000	0.000	0.000
2178T3	drink fountain	0.000	0.000	0.000	0.000
2419P1	Vent	0.000	0.000	0.000	0.000
2419P2	Vent	0.000	0.000	0.996	1.303
2419T3	Doorknob	0.000	0.000	0.000	0.000

*Classroom numbers containing "P" are portable classrooms; those containing "T" are traditional classrooms.

Table 3-41. Summary of Culturable Airborne Microorganisms ($\log_{10}$ [CFU/m^3])

Species	Loc	Est. Pop. Size	n	Pct. Meas.	Mean	50th Pctl	95th Pctl
Cladosporium spp.	Outdr	10	10	100.0	2.57	2.30	
	All	37	37	91.7	1.68	1.61	3.19
	Port	27	27	96.2	1.76	1.79	3.12
	Trad	10	10	80.0	1.46	1.41	
Penicillium spp.	Outdr	10	10	60.0	0.97	1.00	
	All	36	36	52.8	0.72	0.27	2.08
	Port	26	26	50.0	0.72	0.00	1.87
	Trad	10	10	60.0	0.71	0.40	
Aspergillus spp.	Outdr	10	10	0.0	0.00		
	All	36	36	25.0	0.16		1.01
	Port	26	26	23.1	0.15		0.92
	Trad	10	10	30.0	0.19		
Other	Outdr	10	10	70.0	1.14	1.32	
	All	36	36	80.6	0.75	0.83	1.51
	Port	26	26	76.9	0.75	0.87	1.54
	Trad	10	10	90.0	0.75	0.67	
Unknown	Outdr	10	10	80.0	1.45	1.54	
	All	36	36	88.9	1.02	1.06	1.91
	Port	26	26	88.5	1.04	1.06	1.93
	Trad	10	10	90.0	0.97	1.06	

Note: Blank cells indicate cases where the percentile could not be estimated.

4. SUMMARY AND CONCLUSIONS

The Phase II study was an in-person monitoring study conducted from October 2001 through February 2002. It utilized a probability-based sample of California public schools (and random selection of classrooms within the schools) having one or more portable classrooms. The sample of schools selected for the Phase II survey contained 81 eligible schools and was statistically representative of all California public schools that had portable classrooms in the spring and fall of 2001. Statistical estimates of population parameters such as means and proportions were computed using weighted data analysis techniques that generate estimates of means, proportions and regression coefficients and that properly account for features of the sampling design in the estimates of precision (e.g., confidence intervals).

The target population for Phase II of the study is estimated to consist of 6,506 schools containing 69,447 portable classrooms and 126,322 traditional classrooms (195,769 total classrooms). These totals are slightly less than the estimated size of the Phase I population because five schools selected for the Phase II sample were found to have no portable classrooms in the 2001-02 school year. The schools included in the Phase II study population are those California public schools that had traditional classrooms in the spring of 2001 and also have traditional classrooms in the 2001-02 school year.

4.1 Data Completeness and Response Rates

Data were successfully collected (questionnaire data and and/or environmental monitoring data) in 67 of 81 eligible sample schools, resulting in an overall weighted school-level response rate of 83.0%. Such a response rate for school-level participation in Phase II of this study is quite good and limits the possibility for nonresponse bias to seriously affect the results. This high response rate was achieved because we began recruitment early in the school year, obtained written permission from superintendents before contacting principals, and used three experienced staff members for making recruitment calls to superintendents and principals.

In general, conditional classroom-level response rates were good. Exceptions were the following: HVAC status data from HOBO monitors (many of these measurements were judged to be unreliable and hence those data were not weighted); outdoor relative humidity data (not weighted); and CO data (unreliable and not used). On the other hand, the Teacher Questionnaire and the Classroom Form had conditional rates of 93.0% and 98.5%, respectively, which yield overall response rates (i.e., when multiplied by the 83.0% school-level response rate) of 77.2% and 81.7%, respectively. Conditional classroom-level response rates for the other data types varied from 70.6% for some of the VOCs to 98.5% for indoor air aldehydes. When multiplied by the 83.0% school-level response rate, the resulting overall study-level response rates for classroom monitoring data varied from 58.6% for 81.7%.

4.2 Data Quality

Various types of quality control (QC) samples were acquired during Phase II data collection for a subset of the schools/classrooms. These included field blanks, control samples, and duplicate samples. Laboratory performance was monitored through lab controls, lab blanks, and duplicate analysis or duplicate injection methods. In general, the measured levels in the blanks were minimal and relatively uniform. Notable exceptions were acetone and acrolein in the air-aldehyde samples (results not reported) and zinc in the dust-metals. Control recoveries for several analytes (particularly metals in dust) were poor, but most fell within acceptable ranges. Precision was evaluated by computing relative standard deviations (RSDs) for duplicate samples and summarizing them in terms of the median RSD. Similarly, analytical precision was evaluated by computing median RSDs for duplicate analyses and duplicate injections.

4.3 Characteristics of the Target Population of Schools

Weighted estimates of population proportions (and of means and percentiles, for continuous measurements) were generated for selected items from the data collection forms. Among the many estimates produced, the following *school* characteristics were most notable:

- The schools are about equally split between Northern and Southern California (45.5% in the north and 54.5% in the south).
- These schools are mostly suburban schools (75.8% suburban, 17.1% urban, and 7.2% rural).
- These schools are mostly elementary schools (59.2% elementary, 20.7% middle, and 20.1% high school, based on the highest grade offered).
- Many of these schools (40.1%) have 30 or fewer total classrooms, but 4.4% are estimated to have over 30 portable classrooms.
- Most of these schools (87.9%) perform regular HVAC inspection and maintenance.
- Many of these schools (41.7%) are aware of EPA's Tools for Schools program, but few (18.7%) use this program.

These results are consistent with the Phase I findings, except that the awareness and use of the EPA's Tools for Schools program has increased slightly.

Several differences are noted between the proportions of schools that reported environmental problems or complaints regarding environmental conditions in their portable and traditional classrooms in the past year. In particular, higher percentages of schools reported environmental problems and complaints regarding environmental conditions for their portable classrooms. Higher percentages of schools reporting problems or complaints regarding their portable classrooms is consistent with the Phase I findings; however, the percentages of schools reporting problems or complaints is uniformly lower for both portable and traditional classrooms. As noted in the Phase I report, these school-based results must be interpreted with caution because of differences in the numbers of portable and traditional classrooms in the schools and because of differences in the reported frequencies of complaints for the two types of classrooms. It is more appropriate to compare the classrooms using the classroom-level data.

4.4 General Characteristics of the Target Population of Classrooms

Some of the general characteristics of the classroom population are as follows:

- About 63.1% of the classrooms are located in Southern California.

- These classrooms are mostly in suburban schools (75.5% suburban, 17.8% urban, and 6.6% rural).
- These classrooms are mostly in elementary schools (59.0% elementary, 22.9% middle, and 18.1% high school, based on the highest grade offered).

These results are comparable to those observed in Phase I of the study.

General classroom characteristics that were found to be significantly different (at the 5% significance level) between traditional and portable classrooms are highlighted below:

- Portable classrooms usually were newer than traditional classrooms (29.1% versus 83.4% over 15 years old).
- Portable classrooms are much more likely to have had a major addition or replacement in the past three years (83.6% portable classrooms versus none observed for traditional classrooms).
- Portable classrooms were more likely to have carpet or rugs on the floor (82.0% versus 62.9%).
- Portable classrooms were more likely to have water stains on the floor (13.1% versus 2.0%).
- Portable classrooms were more likely to have tack board, fiber/particle board, or plywood walls, whereas traditional classrooms were more likely to have sheetrock, plaster, or other wall material.
- Portable classrooms were less likely to have chalk in the room (21.6% versus 40.8%).
- Portable classrooms were more likely to have pressed wood bookcases in the room (73.1% versus 49.8%).
- Portable classrooms were more likely to have a metal roof (28.5% versus 2.5%).
- Portable classrooms were used somewhat less frequently for general classroom instruction (87.9% versus 96.5%).
-

Moreover, the estimated distribution of the height of the foundation skirt for portable classrooms is as follows: 42.6% are less than 2”, 22.2% are from 2” to 12”, and 35.2% are over 12”.

4.5 HVAC Characteristics

Several of the items from the data collection forms pertain to the condition and operation of the HVAC systems serving the classrooms. Several significant differences between portable and traditional classrooms were observed regarding HVAC characteristics:

- Teachers were more likely to turn off the HVAC system due to high noise levels in portable classrooms (68.3% versus 42.2%).
- The HVAC unit was more likely to be wall mounted for portable classrooms (79.8% versus 9.3%).
- The HVAC unit was more likely to be a heat pump for portable classrooms (94.6% versus 76.9%).
- The heating fuel was more likely to be electricity for portable classrooms (98.1% versus 79.3%).

- The air handling unit was more likely to have good access to its interior for portable classrooms (66.1% versus 35.3%).
- The air filter was more likely to have a light loading of dirt for portable classrooms (51.6% versus 42.9%).
- The size of the gap around the filter was more likely to be less than 1/2" for portable classrooms (71.6% versus 46.3%).
- Mildew or mold was more likely to be found on the filter for portable classrooms (1.3% versus none observed for traditional classrooms).
- The HVAC unit was less likely to have clean condensate drain pans and lines for portable classrooms (30.0% versus 56.7%).
- The HVAC unit was more likely to have standing water in the drain test for portable classrooms (55.3% versus 11.1%).
- A blocked drain was more likely to be observed during the drain test for portable classrooms (36.6% versus 6.8%).
- The HVAC unit was more likely to fail the drain test for portable classrooms (58.5% versus 12.4%).
- The air intake was blocked on the air handling units more often for portable classrooms than for traditional classrooms (10.8% versus 2.7%).

Distributional statistics and hypothesis test results were generated for several continuous measurements related to HVAC performance. These included outdoor air flow (three different metrics: cubic feet per minute [cfm], cfm per chair, and cfm per square foot of classroom area), total supply air flow (cfm), and age of the HVAC unit (years). None of these variables had mean levels that were significantly different (at the 5% level) for portable and traditional classrooms.

The real-time CO_2 data were processed in a manner similar to the temperature and RH data and various summary measures were generated and summarized (e.g., average level, and percent of time that the level exceeded 1000 ppm). None of the means of the selected measures were judged to be statistically different for the portable and traditional classrooms. Average indoor levels (1070 ppm) were more than twice as high as outdoor levels (427 ppm). The indoor levels indicate that classrooms often have inadequate ventilation.

4.6 Lighting and Noise Characteristics

There was no significant difference between portable and traditional classrooms for the teachers' opinions regarding whether or not the classroom lighting was satisfactory. In both cases, most teachers thought the classroom lighting was satisfactory. However, teachers in portable classrooms were significantly more likely to turn off the HVAC system due to high noise levels (68.3% versus 42.2%). It is important to point out that this result is based on a question only about noise. There is some indication that vibration may be a confounding problem that resulted in some teachers deciding to turn the HVAC off. Future studies should pursue this issue. Classroom environmental measurements (HVAC Checklist) also included light and noise measurements. The light intensity was measured in the middle of the classroom. The mean light intensity was significantly higher for traditional classrooms than for portable classrooms (65.2 versus 55.7 foot-candles). Noise was measured both when the HVAC unit was on and again when it was off, in two classroom locations: near the center of the classroom and near the HVAC register. In addition, noise was measured outdoors near the HVAC unit both while it was on and while it was off. None of these six measurements were significantly different (at the 5% significance level) between portable and traditional classrooms.

4.7 Temperature and Humidity Levels

Q-Trak monitoring of temperatures and relative humidity (RH, in %) levels provided data for estimating various summary measures for the monitoring period (confined to at most 7am-4pm). Statistically significant differences between portable and traditional classroom were determined for three of the indoor temperature measures:

- Portable classrooms had temperatures below 17EC (62.6°F) for more of the time (0.01 level): 6.3% versus 3.2%.
- Portable classrooms had temperatures below 20EC (68°F) for more of the time (0.05 level): 27.0% versus 17.0%.
- The mean of the minimum 5-minute temperatures was 17.1E (62.8°F) for portable classrooms versus 17.9E (64.2°F) for traditionals.

None of the RH summary measures exhibited statistically significant differences between the means of the two types of classrooms. However, the portables were estimated to have RH levels over 60% more of the time (an average 16.9% versus 12.6% for traditionals). Average RH levels were about 46%.

4.8 Pollutant Levels

Particle Counts in Indoor Air. One-minute particle counts were obtained every 5 minutes for each of several size fractions. These data were summarized for each classroom (and outdoors) to produce some summary measures for the 7am-4pm time window (e.g., average number of particles per minute for particles of 2.5 µm and less, and average number of particles per minute for particles of 10 µm and less). Characteristics of the distributions of these summary measures were then determined for all classrooms and each type of classroom. Means of these measures for portables and traditionals were not statistically significantly different.

Pollen/Spores in Air. Allergenco slides were analyzed to determine levels of spores that occurred in the air. In general, there were few spores that were observed frequently in either the outdoor or indoor environments. Total Pollen Count and Total Fungal Spores were observed in at least 80% of the slides. No differences in mean levels between portables and traditionals were found.

Aldehydes in Air. Aldehyde air samples were collected in the sample classrooms and at one outdoor location. Of the thirteen specific aldehydes included in the analysis, only two were detected in more than 75% of the samples -- Formaldehyde and Acetaldehyde. For virtually all of the aldehydes, the indoor levels were higher than the outdoor levels, indicating the presence of indoor sources that contribute to the measured levels. Formaldehyde, for example, had a an overall mean level of 13.3 ppb indoors, but only 3.5 ppb outdoors, while the indoor-air 95^{th} percentile was three times higher than the outdoor. Statistically significant differences (0.05 level of significance) between mean levels of portable and traditional classrooms were found for two analytes:

- Formaldehyde (mean of 15.1 for portables versus 12.3 ppb for traditionals)
- o,p-Tolualdehyde, although this analyte has a low percent measurable (~20%).

The distributions of formaldehyde measurements from Phase I and Phase II of this study were compared, even though many differences in the data collection methods and protocols occurred. The Phase I measurements involved use of PF-1 passive monitoring tubes sampling over 7 to 10 days, including nights and weekends when the schools were closed and HVAC systems may have been off, whereas the Phase II measurements were obtained using an active monitoring device during the 6 to 8 hours when classes were in session and HVAC systems were operating normally. Moreover, the Phase I measurements were obtained mostly in the spring, whereas the Phase II measurements were obtained in the fall and winter. Given these differences (colder weather and better air exchange during the monitoring period), it is not surprising that the Phase II formaldehyde concentrations are considerably different than those observed in Phase I, as noted in Table 4-1.

Table 4-1. Formaldehyde Concentrations, Phases I and II

	Sample size (n)		Mean (ppb)		Median (ppb)		95th Percentile (ppb)	
Location	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
Outdoor	NA	62	NA	3.48	NA	2.45	NA	8.05
All classrooms	911	199	27.0	13.29	22.0	12.01	61.7	23.93
Portable	644	135	32.4	15.07	27.1	14.49	71.5	25.78
Traditional	267	64	23.7	12.31	20.0	11.62	55.0	22.35

Volatile Organic Compounds in Air. VOC samples were collected for a subsample of half the sampled schools (usually inside three classrooms and at one outdoor location). Seven of the nine measured VOCs had at least 80% of their measured levels above the detection limit. Only benzene and chloroform had less than 80% detectable. There was a general tendency for the traditional classrooms to exhibit higher VOC concentrations than the portables, but none of the differences in mean concentrations were significant statistically, even at a significance level of 0.10. As in most indoor air quality studies, the measured indoor VOC concentrations were higher than those observed outdoors.

Metals in Floor Dust. For the PCS, metals analyses were obtained from samples collected from the floor dust, reported both in concentration units (ppm) and loading (ng/cm^2) in each of the three classrooms sampled. Dust chemical analyses were done for only a subset of classrooms, and dust samples from the portable classrooms in a given school were composited prior to chemical analysis. Hence population-based weighting (and thus statistical inference to the population) was not possible and formal testing of differences by classroom type is of questionable utility. The data were, however, weighted to reflect the varying numbers of classrooms from school to school and by type of classroom (i.e., to classrooms in those schools for which data were obtained). No important differences between portable and traditional classrooms were determined.

Allergens in Floor Dust. Weighted distributional statistics characterizing the allergen levels from sieved dust samples (dust particles less than 500 Fm) that were collected in the sample classrooms revealed that Canis f1 and Felis d1 were detected in 56% and 74% of the samples, respectively, while the other species were detected less than 10% of the time. The traditional classrooms had higher estimated concentrations for each species than the portables, but the differences were not statistically significant.

Pesticides in Floor Dust. Portable classroom pesticide mean levels were about the same as traditional classroom levels. Six of the twenty measured pesticides were detected in over 80% of the classrooms – chlorpyrifos, cis- and trans-permethrin, o-phenylphenol, piperonyl butoxide, and esfenvalerate. Esfenvalerate had the highest median concentration level (3.83 µg/g). Esfenvalerate had the highest median loading level (0.34 ng/cm^2), while many of the pesticides had median loading levels less than 0.01 ng/cm^2

PAHs in Floor Dust. Six of the PAHs had higher mean loadings (but not concentration levels) for the portables than for the traditional classrooms. The highest PAH levels were found in portable classrooms.

School Reports of Environmental Problems or Complaints in the Past Year. Several differences are noted between the proportions of schools that reported environmental problems with, or complaints regarding, environmental conditions in their portable and traditional classrooms in the past year. Table 4-2 shows that higher percentages of schools reported environmental problems and complaints regarding environmental conditions for their portable classrooms. Higher percentages of schools reporting problems or complaints regarding their portable classrooms is consistent with the Phase I findings; however, the percentages of schools reporting problems or complaints is uniformly lower for both portable and traditional classrooms. Table 3-10 shows that over half of the teachers reported environmental complaints regarding their portable or traditional classrooms.

Table 4-2. Percentages of Schools Reporting Environmental Problems or Complaints in the Past Year

Problem/Complaint	Portable (%)	Traditional (%)
Roof leak	24.3	12.0
Plumbing leak	4.3	2.6
Air quality/odor complaint	20.2	7.0
Mold complaint	13.4	4.4
Temperature complaint	15.8	17.2
Noise complaint	4.3	0.1
Environmental conditions complaint	32.2	18.9

4.9 Factors Affecting Indoor Environmental Quality

Modeling Strategy. Given the massive amount of data generated in the PCS, it is clear that many important and interesting relationships can be examined. As an initial effort towards identifying factors affecting IEQ, a series of weighted regression models were fit that related a selected IEQ variable, Y, to classroom type (portable/traditional indicator) and to other variates. The following notation was defined:

- R = classroom type indicator (= 1 if portable, = 0 otherwise),
- Z = an outdoor measure corresponding to Y. For example, if Y is the logarithm of the classroom formaldehyde levels, then Z would be the logarithm of the outdoor formaldehyde levels at the schools.
- X and X2 =other potential independent variables. These can be continuous variates or can be discrete variates that are coded as a set of dummy (0,1) variables. The models are structured and denoted as follows:

Three different modeling structures were employed, as depicted below:

Structure	Model A Terms			Additional Terms In Model B	Additional Terms In Model C
1	R			X	X2
2	R	Z		X	X2
3	R*	Z*	ZR	X	X2

* Since Structure 3 is used to determine if the effect of Z differs for portables and traditionals (i.e., to determine if the ZR term is significant), separate tests for R and Z within Structure 3 are not possible.

As indicated above, the models are identified by letter and structure; for instance, the model containing R, Z, and a single X would be referred to as Model B2. For cases in which there is not an outdoor measurement analogous to Y, only structure 1 is used. For the present report, all of the C models considered contained CLAGE (classroom age, in years) as one of the two candidate predictors. Thus a C model would be chosen if both CLAGE and the second predictor were statistically significant, a B model would be chosen if only one of the two was statistically significant, and an A model would be chosen if neither was statistically significant. Similarly, a structure 3 model would be used if the ZR interaction is a necessary term, structure 2 would be used if the outdoor covariate Z (but not ZR) is needed, and structure 1 would indicated if neither Z nor ZR were useful predictors.

Factors Affecting Indoor-Air Pollen/Spores. A number of different models for the following Y variables were estimated: Y1 = $\log_{10}$ (Pollen Count), and Y2 = $\log_{10}$ (Total Fungal Spores). Key findings were:

- There was a statistically significant association between indoor and outdoor levels – with higher outdoor levels being associated with higher indoor levels.
- The tests for significance of the classroom-type effect (R) indicated that the portable and traditional classrooms were not significantly different in terms of their Y1 and Y2 levels.
- The tests for significance for the candidate predictors revealed that only one X exhibited statistical significance – namely “windows open” (for Y1), which indicated that classrooms with “windows open today” tended to have lower pollen counts (statistically significant to 0.05 level of significance).

Factors Affecting Indoor-Air Aldehyde Concentrations. Various models for Y1=log(Formaldehyde Concentration), Y2=log(Acetaldehyde Concentration), and Y3=log(o,p-Tolualdehyde Concentration) were estimated; the preferred models for the three species were quite different. For formaldehyde, the type of classroom was generally statistically significant, with portables having higher levels (i.e., a positive coefficient on the portable/traditional indicator variable). The other two aldehydes showed no classroom type effect; however the tolualdehyde models showed a significant outdoor-air by room-type interaction. They also both showed significant associations with their outdoor levels, while the formaldehyde models generally did not show a relationship with the outdoor levels.

Two variables showed the strongest positive relationships with indoor formaldehyde levels: indoor CO_2 (adjusted for outdoor air formaldehyde levels and classroom type) and indoor relative humidity (adjusted for classroom type). These two models accounted for 22% and 32%, respectively, of the total variation in the indoor levels

The model including "pressed wood bookcases" as an X indicator, which also included a significant classroom age variate (positive slope), accounted for only about 14% of the total variation in the indoor formaldehyde levels; however, the effect of this X indicator was 0.303, implying about a 30% increase in formaldehyde levels when pressed wood bookcases were present, and the effect of classroom type was 0.288, implying that portables' levels were about 30% higher than traditionals. The model for acetaldehyde that included "pressed wood bookcases" as an X indicator accounted for about 24% of the total variation in the indoor levels of that analyte. The effect for the X variate was 0.131, indicating a significant increase in the indoor levels when pressed wood bookcases were present, but one that was not as large (relatively) as for formaldehyde. Unfortunately, the disparate classroom age distributions and the small sample sizes for newer traditional classrooms made separation of the classroom type and the classroom age effects infeasible.

Factors Affecting Indoor-Air VOC Concentrations. Models were fit for five VOCs (log scale concentrations) using various candidate predictors. There were significant associations with outdoor levels in virtually all of the models (except for benzene), and these associations appeared somewhat stronger than for the aldehydes. Few of the candidate X predictors were found to be significant. Most of the toluene and m,p-xylene models required structure 3, indicating that the outdoor association varied by classroom type. The toluene and xylene models showed no relation with outdoor levels for portables, and a positive relation for traditional classrooms.

A number of the significant effects for the X variables were counter-intuitive. For example, for tetrachloroethylene, a significant negative association with presence of carpet/rugs was detected. For toluene, significantly lower levels were estimated when new construction/repair activities were on-going (which may reflect the fact that doors and windows might be more frequently closed when those activities were outside of the immediate classroom). The variables in this model accounted for 69% of the total variation in indoor toluene levels.

Factors Affecting Indoor-Air CO_2 Concentrations. Two summary CO_2 measures were modeled: Y1=log(CO_2 Concentration), and Y2=percent of time CO_2 concentrations exceed 1000 ppm. Among the candidate predictors that were considered, classroom age had a significant positive relationship with the CO_2 levels. Also, for Y1, there was a significant positive relation with the outdoor levels. (There was not a corresponding outdoor measurement for Y2.) However, the inclusion of the teacher's rating of IAQ in the Y1 model resulted in an interaction effect between classroom type and outdoor CO_2 levels. A positive relation with the outdoor levels remained for the portables, but not for the traditionals. Based on the log(CO_2) model, the indoor CO_2 levels were estimated to be approximately 30% lower (coefficient on that X was -0.273) when the teachers reported that the IAQ was acceptable. The Y1 and Y2 models both showed a significant effect of school type, with high schools having the highest indoor CO_2 levels.

Factors Affecting Indoor-Air Particle Counts. Models for the following Y variables were estimated: Y1 = log (average number of particles/minute # 2.5 µm and Y2 = log (average number of particles/minute # 10 Fm). Indoor particle levels were significantly associated with outdoor levels. Among the independent variables (X or X2) that were examined as potential predictors, only one was statistically significant: “present of carpets/rugs”, with lower $PM_{2.5}$ levels occurring in rooms with carpets/rugs. For that model, the traditional classrooms also showed significantly lower $PM_{2.5}$ levels than the portable classrooms.

Factors Affecting Noise Associated with HVACs. A single variate was modeled: Y1=the noise level (dBA) measured near the register when the HVAC unit was on. In this case, only model structure 1 is relevant since there is no corresponding outdoor measure. Of the candidate X predictors, only classroom age was statistically significant. For that model, classroom age had a positive effect (older rooms had higher noise levels) and the portables had significantly higher noise levels than the traditionals. This model only accounted for only about 11% of the total variation in the Y1 measure, however.

Factors Affecting Indoor Temperatures. Two types of temperature measures were modeled: Y1=percent of time that the room was below 20EC or 68°F (too cool) and Y2=percent of time that the room was above 23EC or 73°F (too warm). Among the candidate predictors considered, only two predictors appeared significant (school type, and awareness of EPA IAQ tools) for Y2. A meaningful pattern for the latter X variable was not apparent, however, for either Y1 or Y2. Portables and traditionals were not different for Y2, but were significantly different for Y1. The percent of time that the portables had less than 20EC temperatures was larger (by about 10%) than for the traditional classrooms.

4.10 Specially Selected Schools

Fourteen schools were specially selected into the Phase II sample based on their Phase I results (high complaints of environmental problems or high formaldehyde levels). The Phase II formaldehyde levels for the classrooms at these schools were much lower than in Phase I and appeared to match the estimated levels for the total population. Bioaerosol data and biological measurements from surface swabs were also summarized. CO_2 levels measured in the classrooms of the specially-selected schools tended to be lower, on average, than the levels in the general population. Moisture-related problems (e.g., musty odors, mold areas) were reported more frequently for the classrooms in the specially-selected schools.

4.11 Conclusions

- The CA PCS Phase II data base provides a robust basis for statistical inferences regarding the population of schools with portable classrooms because response rates and data completeness were quite good for most analytes and questionnaire items. The exceptions were relatively poor data completeness for HOBO data regarding on/off cycles of HVAC units, CO data, and outdoor relative humidity data. Eighty-three percent of the eligible sample schools provided both questionnaire data and environmental monitoring data, and overall study-level response rates for the weighted classroom-level data (i.e., the products of school-level and classroom-level response rates) varied from 58.6% to 81.7%.

- Analysis of field blank samples, control samples, and duplicate samples revealed that analyte recovery and precision were reasonably good for most analytes. Hence, the quality control samples verified that the environmental measurement and laboratory data quality were satisfactory.

- Facility managers reported problems or complaints regarding indoor environmental quality (e.g., water leaks, odors, mold, noise, and temperature levels) more frequently for their portable classrooms than for their traditional classrooms. Pest-related problems seemed about the same for portable and traditional classrooms.

- Portable and traditional classrooms tend to be different in a number of respects – for example, classroom age, presence of rugs or carpeting, water stains on the floor, construction materials, and other characteristics cited below. Age of the classroom seems to be an important confounding variable to consider when comparing portable and traditional classrooms. The effect of age, however, is difficult to separate from the classroom type effect because of the disparate age distributions of the different room types.

- With respect to the HVAC characteristics, there were a number of significant differences between traditional and portable classrooms. Those related to <u>structure</u> include: physical location of unit, type of fuel (electricity), type of unit (heat pump), and accessibility. With respect to <u>potential indicators of environmental quality</u>, the positive factors include: air filter dirt loading (portable with *light* loading), and tight fitting filter with less than ½" gap (portable with more tightly fitting filters). On the other hand, the portable HVAC filters showed a higher percentage of mildew or mold, dirtier condensate drain pans, clogged drains, and standing water. Also, teachers were more likely to turn off the HVAC system due to high noise levels in portable classrooms. The air flow measurements in traditional and portable classrooms were not significantly different.

- The mean light intensity measured in the center of the classrooms was significantly higher for traditional classrooms relative to portable classrooms. However, in the teachers' opinion, the percentage of teachers in the portable classrooms who considered the lighting to be satisfactory was no different than the opinion expressed by the teachers in the traditional classrooms.

- All classrooms exceeded the new ANSI acoustic standard for classroom noise levels (35 dBA), and a substantial percentage of both portable and traditional classrooms exceeded outdoor noise limits (45 and 55 dBA) set by some California communities. Noise levels measured in both types of classrooms were not statistically different. However, the teachers in portable classrooms were more likely to turn off the HVAC unit due to noise. This noise effect in portable classrooms was supported in the statistical modeling.

- Noise levels measured in both types of classrooms (without students in the classrooms) were not statistically different. However, the teachers in portable classrooms were more likely to turn off the HVAC unit due to noise. The importance of this noise factor for portable classrooms was supported in the statistical modeling. When the noise levels were modeled against age of the classroom, older classrooms had higher noise levels, and portables had significantly higher noise levels than the traditionals.

- Temperature levels were significantly different, with the portable classrooms cooler than the traditional classrooms. Portables also had RH measurements above 60% more of the time than traditional classrooms.

- Assessment of pollutant and CO_2 levels in air revealed the general tendencies depicted in Table 4-3.

- Assessment of pollutant levels in floor dust revealed the following general tendencies:
  - Metals, animal and arthropod allergens, and pesticides generally had comparable levels (both loadings and concentrations, where applicable) in portable and traditional classrooms.
  - Pesticide residues were found in all floor dust samples, indicating the widespread use of a variety of different products in or near classrooms. Six pesticides were detected in over 80% of the rooms, with esfenvalerate (a common insecticide) showing the highest concentration and loading levels. Some of the pesticides are persistent chemicals, lasting for years, while other have an environmental lifetime lasting just weeks; thus, some of the pesticides were likely applied just a week or two prior to the sampling period at some schools in 2001-2002.
  - Similarly, 15 of the 18 metals analyzed for were detected in the floor dust samples. Some, such as arsenic, were detected at higher levels in portables, while others, like lead, were higher in traditional classrooms. Some of the metals are known to have neurological or carcinogenic effects. Most of the 16 PAHs studied (some of which are also known or suspected carcinogens) also were found in over 80% of the classrooms, but the loading levels were low. Most were found at higher levels in the portable classrooms.
  - Dog and cat allergens were found commonly in floor dust. Dust mite and cockroach allergens were found much less often.
  - Several PAHs exhibited higher loadings in portable classrooms than in traditional classrooms, but levels were low.

- Indoor air formaldehyde concentration levels in Phase II were smaller than those in Phase I; there are many differences in procedures and timing of the two data collections.

Table 4-3. Characteristics of Pollutants and CO_2 Measured in Air

Pollutant Type	Summary Statistics and Comparisons of Pollutant Levels		Modeling Results -- *For Selected Species and Selected Predictors*		
	Indoor Levels Vs. Outdoor Levels	**Portable Classroom Mean Vs. Traditional Classroom Mean Test**	**Portable Classroom Vs. Traditional Classroom Test**	**Indoor Levels Related to Outdoor Levels**	**Other Significant Predictors**
CO_2	Indoor higher	About the same	Depends on outdoor level (some models)	Yes (when applicable), depends on room type	Classroom age, and school type and teacher rating of indoor air quality (when classroom age included)
Particle Counts	Outdoor higher	About the same	About the same (most models)	Yes	Presence of carpets/rugs
Pollens and Spores	Outdoor generally higher	About the same	About the same	Yes	Open windows
Aldehydes					
- Formaldehyde	Indoor much higher	Portables higher	Portables higher (most models)	Generally not	Classroom age, school type, general instruction classroom, others related to materials in room, indoor CO_2 levels, indoor RH
- o,p-Tolualdehyde (low % measurable)	Indoor higher	Portables higher	Depends on outdoor level	Yes	General instruction classroom, materials in room, school type
- Others	Indoor generally Higher	About the same	About the same (acetaldehyde)	Yes (acetaldehyde)	General instruction classroom, indoor RH (acetaldehyde)
VOCs	Indoor higher	About the same	About the same, some depend on outdoor level	Yes, some depend on room type	Only a few, varies by analyte

- Classrooms in specially-selected schools appeared to have indoor air formaldehyde concentration levels comparable to those in the general target population (Phase II), but moisture indicators (mold areas and musty odors) were reported more often for the classrooms in the specially-selected schools.

- The Phase II study was successful in generating a massive amount of information about California schools and classrooms. Although the data summaries and analyses described in this report are quite extensive, they clearly represent only a small fraction of the analyses that could be undertaken to address environmental quality issues and related concerns.

- The results from this large, geographically and temporally disperse field study, provide a snap-shot of the IEQ in classrooms across the State. Where standards and guidelines exist, results indicate that there are areas for improvement. Even in the absence of guidelines and standards, results suggest that there are important issues associated with environmental conditions in California K-12 schools that deserve further attention.

5. RECOMMENDATIONS

Recommendations based on the Phase II study fall into two categories:

- Conducting additional analyses of Phase II data
- Improving data quality, completeness and other characteristics in future studies

Conducting Additional Analyses of Phase II Data

Given the magnitude of the data collected in Phase II, it is clear that many additional analyses of the Phase II data may be desirable.

- Additional modeling is needed to better understand the interaction of factors associated with IEQ in schools. Analysts are encouraged to use weighted data analysis methods (where appropriate), since the field data were derived from a probability-based sample having unequal probabilities of selection. Weighted data analysis techniques are particularly important for analyses involving classroom-level data (the vast majority of the data) because portable classrooms were intentionally over-represented in the sample.
- A specific example of further analysis would be to compare the supply air flows to the sum of outdoor air and return air flow. These results should be modeled to understand the relationship to other measured and reported items. Other studies have observed flow imbalance in classrooms, and these data would provide a better understanding of this relationship.
- With such a rich database, analysts should be encouraged to use exploratory analysis techniques, including data mining, to provide opportunities for further research regarding the IEQ in the classrooms.

Improving Data Quality, Completeness and other Characteristics in Future Studies

- Prior to initiating a large-scale field study , it is essential to develop and pilot test a complete data information shell. As described in Section 2.3.1, the information shell displays the requirements for each participating site, the required monitoring, forms, and field steps – all the essentials for the field technicians, laboratory analysts, data processors, and data analysts for tracking and verifying the completeness of all expected activities. Although a draft pilot version of the information shell was tested in the pilot study, many changes to the equipment, types of sample collection, and the data forms occurred after the pilot test, and even after the monitoring began. In addition, the final version of the data information shell did not include data from other sources, such as the allergen data received from California laboratories. Some data problems resulted from using a system that had not been fully tested.

- The final questionnaires and checklists should be tested by the field personnel in actual school settings, before the study begins. These forms should also be processed through the forms processing system (especially optical-scanning forms)to ensure that the results can be accurately processed into the data system.

- The field technicians must be adequately trained in the operation, maintenance, calibration, and data downloading of all instruments prior to field work data collection. Daily status checking by the "at-home" field support staff can identify when problems are occurring and take steps to resolve the problems. Three types of Phase II data were of questionable quality. All three of the instrument types were not tested in the pilot: (1) the HOBO with a sensor to ascertain when the HVAC system was on or off; (2) the CO data, which were essentially all below the limit of detection, except for very unusual instrument noise; and (3) the RH sensor, which provided excellent data for the indoor measurements, but, outdoor RH measurements were incomplete and erratic.

- The Teacher Questionnaire should ask a specific question about vibrations resulting from operating HVAC units. This may be the reason why HVAC units were turned off, instead of the reported reason given, which was noise.

6. REFERENCES

ANSI/ASA (American National Standards Institute, Acoustics Society of America), 2002. Standard S12.60-2002.

ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers), Standard 55-1981. See http://www.ashrae.org.

Bayer, C.W., S.A. Crow, and J. Fisher. Causes of Indoor Air Quality in Schools: Summary of Scientific Research, ORNL/M-6633, Oak Ridge, TN, 1998.

Broadwin R. (2000). Development of and Uses of Health-based Exposure Levels for Indoor Air Contaminants. California Office of Environmental Health Hazard Assessment, Air Toxics and Epidemiology Section, Oakland, CA. Presented at 10th Annual Conference of the International Society of Exposure Analysis, October 24-27, Asilomar, CA.

CASH (Coalition for Adequate School Housing). http://www.cashnet.org/Latest News, November 12, 1999.

City of Davis, Municipal Code, Sec. 24.02.020, daytime residential noise standard.

City of Los Angeles, Ordinance Ch. XI, Art.1, Sec. 111.03, daytime exterior noise standard.

City of Sacramento, Ordinance 8.68.060.

Crandell, C. (1992). Classroom acoustics for hearing-impaired children. Journal of the Acoustical Society of America, 92:2470.

IESNA (Illuminating Engineering Society of North America), 2000. IESNA Lighting Handbook. 9th Edition. New York, NY. Educational Facility Lighting 12-1. As cited in California High Performance Schools (CHPS). CHPS Best Practices Manual, Electrical Lighting: Volume IIA, p. 150. Eley and Associates, 2001. http://www.chps.net.

Jenkins, P.L., T.J. Phillips, E.J. Mulberg, and S.P. Hui. Activity Patterns of California: Use and Proximity to Indoor Pollutant Sources. *Atmos. Environ.* 26A: 2141-2148, 1992.

Kass, G. (1980). "An Exploratory Technique for Investigating Large Quantities of Categorical Data," *Applied Statistics*, Vol. 29, No. 2, pp. 119-127.

Liu, K., K. Sexton, S.B. Hayward, M. Petreas, L. Webber, and B. Change (1986). "Determinants of Formaldehyde Concentrations inside Mobile Homes." Presented at the 79th Annual Meeting of the Air Pollution Control Association.

OEHHA (California Office of Environmental Health Hazard Assessment),1992. Expedited Cancer Potency Values and Proposed Regulatory Levels for Certain Proposition 65 Carcinogens.

OEHHA, Reproductive and Cancer Hazard Section, Oakland, CA. http://www.oehha.org/prop65/pdf/expcancer.pdf.

OEHHA, March 1999. Determination of Acute Reference Exposure Levels for Airborne Toxicants, Acute Toxicity Summary: Formaldehyde. OEHHA, Air Toxicology and Epidemiology Section, Oakland, CA. http://www.oehha.ca.gov/air/acute_rels/pdf/50000A.pdf.

OEHHA, 2001. All Chronic Reference Exposure Levels Adopted by OEHHA as of December 2001. Chronic Toxicity Summary, Formaldehyde., OEHHA, Air Toxicology and Epidemiology Section, Oakland, CA. http://www.oehha.ca.gov/air/chronic_rels/pdf/50000.pdf.

Pellizzari, E.D., R.L. Perritt, and C.A. Clayton (1999). "National Human Exposure Assessment Survey (NHEXAS): Exploratory Survey of Exposure among Population Subgroups in EPA Region V." *Journal of Exposure Assessment and Environmental Epidemiology*, Vol. 9, No. 1, pp. 49-55.

Oh, H.L. and F.J. Scheuren (1983). Weighting Adjustment for Unit Nonresponse. In: *Incomplete Data in Sample Surveys, Volume 2: Theory and Bibliographies*, Madow, W.G., Olkin, I., and Rubin, D.B., eds., Academic Press, New York, NY, pp. 143-184.

Pellizzari, E.D., R.L. Perritt, and C.A. Clayton (1999). "National Human Exposure Assessment Survey (NHEXAS): Exploratory Survey of Exposure among Population Subgroups in EPA Region V." *Journal of Exposure Assessment and Environmental Epidemiology*, Vol. 9, No. 1, pp. 49-55.

Phillips, T.J., P.L. Jenkins, and E.J. Mulberg. Children in California: Activity Patterns and presence of Pollutant Sources. Paper #91-172.5. Proceedings, 84th Annual Meeting, AWMA, Vancouver, BC, June 16-21, 1991.

Robinson, J.P. and J. Thomas. Time Spent in Activities, Locations and Microenvironments. A California-National Comparison Project Report, U.S. EPA, Las Vegas, NV, 1991.

RTI, *SUDAAN User's Manual, Release 8.0* (2001)

Torres, V., M. Sanders, and R. Corsi (2002). "Texas Elementary School Indoor Air Study (TESIAS): Overview and Major Findings." Proceeds of Indoor Air 2002, pp. 80-85.

WHO (World Health Organization), 1999. Guidelines for Community Noise. Berglund, B., Lindvall, T., and Schwela, D. (ed.). Http://www.who.int/peh/noise/guidelines2.html.

GLOSSARY OF TERMS

Term	Definition
Active/Passive Sampling	Active sampling depends on pumping or similar processes to collect the sample, such as was used for VOC and Aldehyde sample collection; whereas passive sampling involves non-mechanical processes, like diffusion, such as was used in Phase I for the formaldehyde sample collection
Air Changes per Hour	Volume of air moved in one hour. One air change per hour is a room, home, or building means that all the air in that environment will be replaced in one hour. (ACH)
Air Conditioning	The process of treating air to meet the requirements of a conditioned space by controlling its temperature, humidity, cleanliness, and distribution.
Air Exchange Rate	The rate at which outside air replaces indoor air in a space. Expressed in units of air changes per hour or cubic feet per minute.
Air Handling Unit	Refers to equipment that includes a blower or fan, heating and/or cooling coils, and related equipment such as controls, condensate drain pans, and air filters. Does not include ductwork, registers, or grilles, or boilers and chillers.
Allergen	A chemical or biological substance (e.g., pollen, animal dander, or house dust mite proteins) that induces an allergic state or reaction, characterized by hypersensitivity.
Bacteria	Microscopic living organism.
Biological Contaminants	Agents derived from or that are living organisms (e.g., viruses, bacteria, fungi, and mammal and bird antigens) that can be inhaled and can cause many types of health effects including allergic reactions, respiratory disorders, hypersensitivity diseases, and infectious diseases. Also referred to as microbiologicals or microbials.
Chemical Classes/Families	Groups of chemicals by common characteristics, such as VOCs, PAHs, Aldehydes, carbonyls, metals, pesticides
Comfort measures	Temperature, relative humidity, noise and light
Composite Samples	Combined samples of similar types to get an overall average result, for example, composite floor dust samples collected in the

	two portable classrooms. Composite samples are also used to obtain detectable amounts of analytes when single samples may be insufficient.
Cross-tabulation	Tabulation of the levels of one categorical variable crossed with the levels of a second categorical variable
Dampers	Controls that vary airflow through an air outlet, inlet, or duct. A damper position may be immovable, manually adjustable, or part of an automated control system.
Diffusers and Grilles	Components of the ventilation system that distribute and diffuse air to promote air circulation in the occupied space. Diffusers supply air and grilles return air.
Distribution	Relative frequency of occurrence of values in a population or sample
Domain	Subpopulation regarding which statistical inferences are defined (e.g., portable classrooms)
Electrostatic Precipitator	An air pollution control device that removes particles from an air stream. The ESP imparts an electrical charge to particles causing them to adhere to metal plates inside the precipitator.
Fungi	A group of organisms that lack chlorophyll, including molds, mildews, yeasts, mushrooms.
Humidity	The measure of moisture in the atmosphere.
Limit of Detection (LOD)	Lowest detectable concentration of a pollutant for a sampling and/or analytical procedure. This can be determined by a number of different methods, depending on the type of sample.
Mail Survey	An information gathering study that utilizes the mail for distributing and returning the information, such as was used in Phase I.
Makeup Air	Outdoor air supplied to replace exhaust air and exfiltration.
Microbes	Microscopic organisms such as algae, insects, viruses, bacteria, fungi, and protozoa, some of which cause diseases.
Microbiologicals	See “Biological Contaminants.”
Micron	A unit of linear measure equal to one millionth of a meter.

Microorganism	A microscopic organism, especially a bacterium, fungus, or protozoan.
Natural Ventilation	The movement of outdoor air into a space through intentionally provided openings, such as windows and doors, or through non-powered ventilators or by infiltration.
Non-response	Lack of data for a sample unit for which data were intended to be collected, due to subjects declining to participate or provide certain information
Phase I	The mail survey conducted in the spring-early summer of 2001. It consisted of two questionnaires, a facilities questionnaire and a teachers' questionnaire, and for a subsample of the schools, passive formaldehyde samplers
Phase II	The field study conducted in October 2001 through February 2002. It consisted of a number of active monitoring and sampling of indoor and outdoor air pollutants, measurement of indoor thermal, noise, and lighting conditions, and questionnaires and inspections regarding building conditions and maintenance practices.
Plenum	Air compartment connected to a duct or ducts.
Portable Classrooms	Classrooms that are designed and constructed to be moveable and transportable over public streets, also known as temporary or relocatable classrooms.
Quality Control (QC)	Internal checks on the operation of sample collection or sample analysis. Methods for determining the operation include blanks, spiked samples, flow checks, duplicate samples. QC measures can be used to determine accuracy, bias, and precision of the data reported.
Real-time Monitoring	This type of environmental measurement gives instantaneous (or nearly so, depending on the sampling rate/time in detector) information at the point of sampling. Examples include measurements for CO, CO_2, particle counts, temperature, relative humidity, lighting, and noise.
Recirculated Air	Air removed from the conditioned space and used for ventilation, heating, cooling, humidification, or dehumidification.
Reference Exposure Level (REL)	The concentration level at or below which no adverse health effects are anticipated for a specified exposure duration. RELs are based on the most sensitive, relevant, adverse health effect reported in the medical and toxicological literature. RELs

	are designed to protect the most sensitive individuals in the population by the inclusion of margins of safety. Since margins of safety are incorporated to address data gaps and uncertainties, exceeding the REL does not automatically indicate an adverse health impact. OEHHA provides acute (1-hour), chronic (lifetime, non-cancer), and indoor (1-hour, non-cancer) RELs for a number of chemicals.
Return Air	Air removed from a space to be then recirculated or exhausted.
Selectivity	Ability to discriminate an analytical response for a specific chemical, biological, or physical characteristic
Sensitivity	Change in the detection method's response (slope) as a function of incremental changes in analyte concentration
Sorbent Material	Types of material used for collecting and retaining the sample for analysis such as Carbotrap, Carbopack.
Sorbent Tubes	Tubes containing some adsorbing/absorbing material for capturing and preconcentrating/enriching the target analytes
Specially-Selected Schools	14 schools and the three respective classrooms in the Phase I sample that appeared to have the greatest potential for indoor environmental quality (IEQ) problems and, hence, were all included in the Phase II sample as a separate strata
Strata	Sub-groups within the target population that were sampled independently. For example, see Table 2-7 for the strata used for the Phase II sample.
Stratified Random Sampling	Random samples are selected from each of the strata. The sampling rate or selection probability for each strata can differ, depending on the study design.
Supply Air	Air delivered to the conditioned space and used for ventilation, heating, cooling, humidification, or dehumidification.
Target population	The set of schools and/or classrooms about which statistical inferences are supported by the study design, specifically all California K-12 public schools that had portable classrooms in both the spring and fall of 2001 (spring of 2001 only for Phase I), and all classrooms in those schools
Traditional classrooms	Site-built classrooms in permanent school buildings

Variable Air Volume System	Air handling system that conditions the air to a constant temperature and varies the outside airflow to ensure thermal comfort.
Ventilation	The process of supplying and removing air by natural or mechanical means to and from any space.
Volatile Organic Compounds	Compounds that evaporate from the many housekeeping, maintenance, and building products made with organic chemicals. These compounds are released from products that are being used and that are in storage.
Weights (or sample weights)	Statistical weighting factors that are used to remove the bias due to differential sampling rates and to reduce the bias due to differential rates of non-response

GLOSSARY OF ABBREVIATIONS AND SYMBOLS

Term	Definition
ACH	air changes per hour
AHU	air handling unit of the HVAC system
ARB	California Air Resources Board
^oC	degrees Celsius
CFM	cubic feet per minute
CFU	colony forming units
cm^2	square centimeter
CO	carbon monoxide
CO_2	carbon dioxide
DHS	California Department of Health Services
DNPH	2,4-dinitrophenyl hydrazine
^oF	degrees Fahrenheit
GC	gas chromatography
GC/MS	gas chromatography coupled to mass spectrometry
HPLC	high performance liquid chromatography
HVAC	heating, ventilating, and air conditioning. Refers to the system including control equipment servicing the building or classroom.
IAQ	indoor air quality
ICP/MS	inductively coupled plasma-mass spectrometry
IEQ	indoor environmental quality
kg	kilogram
l/min.	liters per minute (flow rate)
LOD	limit of detection
m^2	square meter
m^3	cubic meter
:g	microgram
:g/g	microgram per gram (concentration)
mg	milligram
mg/kg	milligram per kilogram (concentration)
ml	milliliter
ng	nanogram
ng/g	nanogram/gram (concentration)
No.	number
OEHHA	California Office of Environmental Health Hazard Assessment
PAHs	polynulcear aromatic hydrocarbons
PCS	California Portable Classrooms Study
PM2.5	Particles with aerodynamic diameter less than 2.5 microns
PM10	Particles with aerodynamic diameter less than 10 microns
ppb	parts per billion
ppm	parts per million
QC	quality control
REL	Reference Exposure Level
RH	relative humidity

RSD	relative standard deviation, calculated as standard deviation divided by mean, expressed as a %
SD	standard deviation
T	temperature
UV	ultraviolet (light)
VAV	variable air volume system
VOCs	volatile organic compounds, e.g., benzene, toluene.